LAWES AGRICULTURAL TRUST

Rothamsted Experimental Station
Harpenden

REPORT 1923-24

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

To be obtained only of the Secretary

Price 2/6 (Foreign Postage extra)

Telephone and Telegrams
Harpenden 21

Station
Harpenden L.M.S

HARPENDEN
PRINTED BY D. J. JEFFERY, VAUGHAN ROAD
1925

LAWES AGRICULTURAL TRUST

Rothamsted Experimental Station
Harpenden

REPORT 1923-24

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

To be obtained only of the Secretary

Price 2/6 (Foreign Postage extra)

Telephone and Telegrams
Harpenden 21

Station
Harpenden L.M.S.

HARPENDEN
PRINTED BY D. J. JEFFERY, VAUGHAN ROAD
1925

The New Rothamsted Laboratories, erected 1914-1916

REPORT

1923-24

Contents

Experimental Station Staff

Director: SIR E. JOHN RUSSELL, D.Sc., F.R.S.

Assistant Director: B. A. KEEN, D.Sc., F.Inst.P.

INSTITUTE of PLANT NUTRITION and SOIL PROBLEMS

The James Mason Bacteriological Laboratory—

Head of Department ...	H. G. THORNTON, B.A.
Assistant Bacteriologist ...	P. H. H. GRAY, M.A.
Post Graduate Research Workers	N. GANGULEE, B.Sc. (Prof. Agric. Univ. Calcutta). V. SUBRAMANYAN, B.E.
Laboratory Attendant ...	SHEILA ARNOLD.

Botanical Laboratory—

Head of Department ...	WINIFRED E. BRENCHLEY, D.Sc., F.L.S.
Assistant Botanist ...	KATHERINE WARINGTON, M.Sc.
Laboratory Assistant ...	GRACE BASSIL.
Laboratory Attendants ...	LIZZIE KINGHAM. KATHLEEN DELLAR.

Chemical Laboratory—

Head of Department ...	H. J. PAGE, B.Sc., A.I.C.
Assistant Chemists ...	G. C. SAWYER. R. G WARREN, B.Sc.
Post Graduate Research Workers (Ministry of Agriculture Research Scholars)	W. WILLIAMS, B.Sc. R. P. HOBSON, B.Sc., B.Sc. (Agric.), A.I.C. A. W. GREENHILL, M.Sc.
Barley Investigations (Institute of Brewing Research Scheme)	H. LLOYD HIND, B.Sc., F.I.C. H. THREADGOLD, B.Sc., A.I.C.
Special Assistant	E. GREY.
Laboratory Steward and Store Keeper	A. OGGELSBY.
Laboratory Assistants ...	A. H. BOWDEN. G. LAWRENCE. F. SEABROOK.
Laboratory Attendants ...	GLADYS TEBB. MARGARET JENKINSON.

Laboratory for Fermentation Work—

Head of Department ...	E. H. RICHARDS, B.Sc., F.I.C.
Assistant Chemist ...	R. L. AMOORE, F.I.C.
Post Graduate Research Worker	R. D. REGE, M.Sc.

Laboratory for Antiseptics, Insecticides, etc.—

Head of Department ...	F. TATTERSFIELD, B.Sc., F.I.C.
Assistant Chemists ...	W. A. ROACH, B.Sc., A.R.C.S., A.I.C.
	C. T. GIMINGHAM, F.I.C.
Laboratory Attendant ...	IRENE RANDALL.

Physical Laboratory—

Head of Department ...	B. A. KEEN, D.Sc., F.Inst.P. (Goldsmiths' Company Physicist).
Assistant Physical Chemist	E. M. CROWTHER, D.Sc., F.I.C. (Empire Cotton Growing Corporation Soil Physicist).
Assistant Physicists ...	W. B. HAINES, B.Sc., F.Inst.P., D.I.C.
	J. R. H. COUTTS, M.Sc., A.Inst.P.
Post Graduate Research Workers	A. N. PURI, M.Sc., PH.D. (Punjab Drainage Board Scholar).
	W. S. MARTIN, Ph.D. (Empire Cotton Growing Corporation Student).
Laboratory Assistants ...	W. GAME.
	ANNIE MACKNESS.
Laboratory Attendant ...	R.F.S. HEARMON.

Protozoological Laboratory—

Head of Department ...	D. WARD CUTLER, M.A., F.L.S.
Assistant Protozoologists	LETTICE M. CRUMP, M.Sc.
	H. SANDON, M.A.
	ANNIE DIXON, M.Sc.
Laboratory Assistant ...	MABEL DUNKLEY.

Statistical Laboratory—

Head of Department ...	R. A. Fisher, M.A.
Assistant Statistician ...	Winifred A. Mackenzie, M.Sc. (Econ.).
Post Graduate Research Worker	L. H. C. Tippett, B.Sc., A.R.C.S.
Computer (Honorary) ...	W. D. Christmas.
Assistant Computers ...	A. D. Dunkley.
	Kathleen Abbott.

INSTITUTE of PLANT PATHOLOGY

Entomological Laboratory—

Head of Department ...	A. D. Imms, M.A., D.Sc., F.L.S.
Assistant Entomologists ...	J. Davidson, D.Sc., F.L.S.
	H. M. Morris, M.Sc.
	D. M. T. Morland, M.A.
	A. M. Altson, F.E.S.
Post Graduate Research Worker	R. C. Fisher, Ph.D.
Field Assistant	A. C. Rolt.
Laboratory Attendants ...	Edith Cooper.
	Elizabeth Sibley.

Mycological Laboratory—

Head of Department ...	W. B. Brierley, D.Sc., F.L.S
Assistant Mycologists ...	J. Henderson Smith, M.B. Ch.B., B.A.
	Mary D. Glynne, M.Sc.
Algologist	B. Muriel Bristol Roach, D.Sc.
Post Graduate Research Worker	F. F. L. Chodat, D.Sc. (Fellow Rockefeller International Education Board).
Laboratory Attendants ...	Lyla Ives.
	Doris Tuffin.

FIELD EXPERIMENTS

Ecologist	T. Eden, M.Sc.
Plant Physiologist ...	E. J. Maskell, M.A., Ph.D.
Guide Demonstrator ...	H. V. Garner, M.A., B.Sc.
Plant Physiologists for Special Experiments ...	F. G. Gregory, D.Sc. A. T. Legg. E. Dorothy Kay.

FARM and EXPERIMENTAL FIELDS

Farm Director	C. Heigham, M.A., Diploma Agric. (Cantab.).
Superintendent of Experimental Fields	B. Weston.
Assistant Supervisor ...	E. Cole.

LIBRARY

Librarian	Mary S. Aslin.

SECRETARIAL STAFF

Secretary	W. Barnicot.
Director's Private Secretary	Muriel L. Dick, B.A.
Senior Clerk	Constance K. Catton.
Junior Clerks	Beatrice Allard. Nora Leverton.

Engineer and Caretaker ...	W. Pearce.
Photography and Instruments	V. Stansfield.

THE ASSOCIATED FARMS

Woburn Experimental Farm.

Hon. Local Director ...	J. A. Voelcker, M.A., Ph.D.
Resident Chemist and Manager of Experiments	A. Blenkinsop, M.Sc.

Leadon Court.

(The property of E. D. Simon, Esq.)

Manager: J. H. Hellier, Diploma Agric. (Cantab.)

Publications of the Rothamsted Experimental Station

For Farmers

"The Book of the Rothamsted Experiments," by Sir A. D. Hall, M.A. (Oxon.), F.R.S., Third Edition revised by Sir E. J. Russell, D.Sc., F.R.S. John Murray, 50, Albemarle Street, London, W.1 (in preparation).

"Manuring for Higher Crop Production," by E. J. Russell, 1917. The University Press, Cambridge. 5/6.

"Weeds of Farmland," by Winifred E. Brenchley, D.Sc., F.L.S., 1920. Longmans, Green & Co., 39, Paternoster Row, London, E.C.4. 12/6.

"Farm Soil and its Improvement," by E. J. Russell, 1923. Benn Bros., Ltd., 8, Bouverie Street, London, E.C.4. 7/6.

For Students and Agricultural Experts

"The Rothamsted Memoirs on Agricultural Science," Quarto Series, vols. 1-3 (1859-1883), 20/- each. Octavo, vols. 1-7 (1847-1898), 30/- each. Royal octavo, vol. 8 (1900-1912), vol. 9 (1909-1916), vol. 10 (1916-1920), vol. 11 (1920-1922), 32/6 each. Postage extra. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

"The Rothamsted Monographs on Agricultural Science," edited by Sir E. J. Russell, D.Sc., F.R.S.

- "Soil Conditions and Plant Growth," by E. J. Russell, Fourth Edition, 1921. Longmans, Green & Co., 39, Paternoster Row, London, E.C.4. 16/-.
- "The Micro-Organisms of the Soil," by E. J. Russell and Staff of the Rothamsted Experimental Station, 1923. Longmans, Green & Co., 39, Paternoster Row, London, E.C.4. 7/6.
- "Manuring of Grassland for Hay," by Winifred E. Brenchley, D.Sc., 1924, Longmans, Green & Co., 39, Paternoster Row, London, E.C.4. 12/6.
- "A List of British Aphides" (including notes on their recorded distribution and food-plants in Britain, and a food-plant index), by J. Davidson, D.Sc., F.L.S. Longmans, Green & Co., 39, Paternoster Row, London, E.C.4 (in the Press).

The following Monographs are in preparation :—

- "Soil Physics," by B. A. Keen, D.Sc.
- "Soil Protozoa," by D. W. Cutler, M.A., and Lettice M. Crump, M.Sc.
- "Soil Bacteria," by H. G. Thornton, B.A.

"Soil Fungi and Algæ," by W. B. Brierley, D.Sc., and B. Muriel Bristol Roach, D.Sc.

"Chemical Changes in the Soil," by H. J. Page, B.Sc.

"Inorganic Plant Poisons and Stimulants," by Winifred E. Brenchley, 1914. The University Press, Cambridge. 9/-.

"A General Textbook of Entomology," by A. D. Imms, M.A., D.Sc. 1925. Methuen & Co., Essex Street, Strand, London, W.C.2. 36/-.

"Statistical Methods for Research Workers," by R. A. Fisher, M.A. Oliver & Boyd, Edinburgh (in the Press).

The following are obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts :—

"Agricultural Investigations at Rothamsted, England, during a Period of 50 Years," by Sir Joseph Henry Gilbert, M.A., LL.D., F.R.S., etc., 1895. 3/6.

"Six Lectures on the Investigations at Rothamsted Experimental Station," by Robert Warington, F.R.S., 1891. 2/-.

"Guide to the Experimental Plots. Rothamsted Experimental Station, Harpenden." 1913. John Murray, 50, Albemarle Street, W. 1/-.

"Plans and Data of the Experimental Plots." 1925. 6d.

"Catalogue of Journals and Periodicals in the Rothamsted Library." 1921. 2/6.

"A Descriptive Catalogue of Printed Books on Agriculture from 1471 to 1840, contained in the Rothamsted Library." 1925. 336 pp. 20 illustrations. Cloth cover, 8/6; paper cover, 6/6. (In the press.)

For use in Farm Institutes

"A Student's Book on Soils and Manures," by E. J. Russell, 1919. The University Press, Cambridge. 8/-.

For use in Schools

"Lessons on Soil," by E. J. Russell, 1912. The University Press, Cambridge. 3/-.

For General Readers

"The Fertility of the Soil," by E. J. Russell, 1913. The University Press, Cambridge. 4/-.

"The Possibilities of British Agriculture," by Sir Henry Rew, K.C.B., and Sir E. J. Russell, D.Sc., F.R.S. 1923. John Murray, 50, Albemarle Street, London, W.1. 8d.

"Personal Reminiscences of Rothamsted Experimental Station," 1872-1922, by E. Grey, formerly Superintendent of the Experimental Fields. 5/-. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

INTRODUCTION

The Rothamsted Experimental Station was founded in 1843 by the late Sir J. B. Lawes, with whom was associated Sir J. H. Gilbert for a period of nearly 60 years. Lawes died in 1900 and Gilbert in 1901; they were succeeded by Sir A. D. Hall from 1902 to 1912, when the present Director, Sir E. J. Russell, was appointed.

For many years the work was maintained entirely at the expense of Sir J. B. Lawes, at first by direct payment, and from 1889 onwards out of an income of £2,400, arising from the endowment fund of £100,000 given by him to the Lawes Agricultural Trust. In 1904 the Society for extending the Rothamsted Experiments was instituted for the purpose of providing funds for expansion. In 1906 Mr. J. F. Mason built the Bacteriological Laboratory; in 1907 the Goldsmiths' Company generously provided a further endowment of £10,000, the income of which is to be devoted to the investigation of the soil, thus raising the total income of the Station to £2,800. In 1911 the Development Commissioners made their first grant to the Station. Since then Government grants have been made annually, and for the year 1924-25 the Ministry of Agriculture has made a grant of £26,480 for the work of the Station. Viscount Elveden, M.P., has generously borne the cost of a chemist for studying farmyard manure since 1913 and has recently provided funds for the fitting up of a laboratory workshop, while Lady Ludlow, Sir Otto Beit, Mr. Robert Mond, Mr. T. H. Riches, Mr. and Mrs. D. MacAlister and other donors have from time to time generously provided funds for special apparatus and equipment. The Sulphate of Ammonia Federation and the Fertiliser Manufacturers' Association jointly defray the cost of a Guide Demonstrator for the field plots and the Potash Syndicate, Messrs. Brunner Mond & Co. and other firms have given substantial assistance.

The laboratories have been entirely rebuilt. The main block was opened in 1919, and is devoted to the study of soil and plant nutrition problems; a new block has been erected for plant pathology at a cost of £21,135 provided by the Ministry of Agriculture out of the Development Fund. The library has been much expanded and now contains some 20,000 volumes dealing with agriculture and cognate subjects. The catalogue of agricultural books is now being printed.

The most important development of recent years has been the reorganisation of the work of the Station so as to bring it into touch with modern conditions of agriculture on the one side and of science on the other. So far as the laboratories are concerned this was completed in 1922; the reorganisation of the farm under

the new Farm Director, Mr. C. Heigham, is now well in hand and the new arrangements for the improvement of field observations and records are already in operation.

The general method of investigation at Rothamsted is to start from the farm and work to the laboratory or vice versa.

There are four great divisions in the laboratory—biological, chemical, physical and statistical—which may be regarded as the pillars on which the whole structure rests. But the method of investigation differs from that of an ordinary scientific laboratory where the problem is usually narrowed down so closely that only one factor is concerned. On the farm such narrowing is impossible; many factors may operate and elimination results in conditions so artificial as to render the enquiry meaningless. In place, therefore, of the ordinary single factor method of the scientific laboratory, liberal use is made of statistical methods which allow the investigation of cases where several factors vary simultaneously. In the crop investigations a large number of field observations are made; these are then treated statistically to ascertain the varying degrees to which they are related to other factors—such as rainfall, temperature, etc.—and to indicate the probable nature of the relationships. Thus the complex problem becomes reduced to a number of simpler ones susceptible of laboratory investigation.

It has been found desirable to widen the scope of the work by repeating some of the more important experiments elsewhere, and various centres in different parts of the country have been selected for this purpose.

In October, 1921, the Station undertook, so long as its funds should allow, to carry on the continuous wheat and barley experiments at the Woburn Experimental Farm, till then conducted by the Royal Agricultural Society, and Dr. Voelcker gives his services as Honorary Local Director. In December, 1922, E. D. Simon, Esq., generously placed his Leadon Court farm at the disposal of the Station for experimental purposes. This is being used as a large scale test of the soiling system for keeping dairy cows (see p. 41).

The acceptance by Lord Bledisloe in November, 1924, of the office of Parliamentary Secretary to the Ministry of Agriculture and Deputy Minister of Fisheries necessitated his vacation of the chairmanship of the Lawes Agricultural Trust Committee, which he had held since October, 1920. Lord Bledisloe consistently favoured the policy of extending the activities of Rothamsted outside the Station and bringing the scientific workers more closely into touch with the actual farmers themselves. This policy has proved stimulating and beneficial to the Station and the results have abundantly justified its wisdom.

Lord Clinton has now been elected Chairman in place of Lord Bledisloe.

REPORT FOR THE YEARS 1923-24

The purpose of the work at Rothamsted is to discover the principles underlying the great facts of agriculture, and to put the knowledge thus gained into a form in which it can be used by teachers, experts and farmers for the upraising of country life, and the improvement of the standard of farming. The criterion by which the work is to be judged is its trustworthiness; if it satisfies this condition it will assuredly find its place in farm practice, or as part of the material which teachers can use in country schools, farm institutes and agricultural colleges for the education of their pupils.

The most fundamental part of agriculture is the production of crops, and to this subject most of the Rothamsted work is devoted. The problems fall into three groups concerned respectively with the cultivation of the soil, the feeding of the plant and the maintenance of healthy conditions of plant growth.

The field work at Rothamsted for many years centred round the effects of artificial manures and of farmyard manure in the production of farm crops. The farmers of Great Britain make some £14,000,000 worth of farmyard manure each year, and they spend on artificial manures a sum which is probably not much short of £8,000,000 a year. The waste of farmyard manure is known to be considerable, and it is certain that the artificials are not used as well as they could be. Numerous measurements indicate that only about 60 or 70 per cent. of the nitrogen given in artificial fertilisers is recovered in the crop; the remaining 30 or 40 per cent. is wasted. It has been estimated that the loss from wastage of farmyard manure and of artificials in the soil represents a sum probably not less than some £8,000,000 or £9,000,000 per annum.

The Rothamsted plots, while demonstrating the effects of the various artificial fertilisers on farm crops, are not in themselves sufficient to afford guidance as to the most suitable kind of manuring for any particular crop or soil type. The influence of soil and season on the effectiveness of manures is very considerable but until recently it has not been studied in detail: a beginning has now been made. Two methods of investigation are followed: In one, the analytical method, the Rothamsted data, which now extend over periods varying from 60 to 80 years, are being examined by statistical methods so as to show the effect of climatic elements, rainfall, sunshine, etc., on yields. The other is the observational method, intended to elicit the basic facts which can then be further studied in the laboratory. It is pursued in several ways. The Rothamsted plots

are kept under close observation by a team of three workers, Messrs. Garner, Eden and Maskell, who view them respectively from the standpoints of the agriculturist, the ecologist and the plant physiologist. This gives information about the climatic factors but not much about the soil. Certain of the Rothamsted experiments are therefore repeated as precisely as is practicable on a number of farms chosen in different parts of the country to represent important soil and climatic conditions.

The analytical method has so far been applied only to the wheat and barley data.

Of the various climatic factors affecting wheat at Rothamsted, rainfall is the most important, accounting for some 30 to 40 per cent. of the whole climatic effect. Broadly speaking, winter rainfall is harmful, especially on land in good condition, spring rain is less harmful or even beneficial, and summer rain is harmful, but the detailed effects depend on the kind of manuring. No less than five different types of action are found on the Broadbalk field. When fertility is low, winter rain has but little bad effect; when, however, the land is in good condition, each inch of rain above the average in January reduces the harvest by one or two bushels of grain per acre. May rainfall, on the other hand, may do good, especially on land where the nitrogen supply is large relative to the potash. It further appears that wheat receiving farmyard manure is happier in a dry climate that in a wet one, while certain schemes of artificial manures work out better under wet conditions than others do.

The investigations of Broadbalk and other Rothamsted data have brought to light several interesting ways in which farmyard manure behaves quite differently from artificial manures. The variation in crop yield from year to year is less with farmyard manure than with artificials; so also is the variation in the effect of rain at different times of growth; while the land deteriorates less under the heavy strain of continuous cropping. On the rotation land clover residues are found to have a steadying effect on the yield of wheat similar to that shown by farmyard manure.

The advantage of the statistical treatment is that it enables definite expression to be given to these facts, so that the complex field phenomena become reduced to a series of single factor investigations which can be dealt with by the methods of plant physiology.

FERTILISER INVESTIGATIONS.

The fertiliser investigations are in the main reported under the various crop headings; reference must, however, be made here to certain general results of considerable interest that have been obtained.

Notwithstanding the wetness and general bad character of the seasons, especially of 1924, nitrogenous manures exerted their full effect. The average gains from the use of 1 cwt. sulphate

of ammonia in the experiments at Rothamsted and at outside centres inspected by us were as follows :—

	1922 Rothamsted.	1923 Rothamsted.	1924 Rothamsted.	1924 Outside Centres.	Average of all Soils and Seasons to 1920
Wheat, bu. ...	3·25			4·3–6	4·5
Barley, bu. ...	5·5	4·5	8·16	3·5	6·5
Oats, bu. ...		8.3			7
Potatoes, cwt.	20	22–25	20		20
Swedes, cwt.	20	25	5–9	30	20 N. Country 10 S. Country

SIZE OF DRESSING AND TIME OF APPLICATION.

The effect of doubling the nitrogenous dressing and supplying 2 cwt. sulphate of ammonia per acre is to give a further increase in crop. In the case of cereals this second increase is not infrequently greater than the first, so that the effect of the double dressing is to give more than double the increase obtained from the single one. This was shown both in 1923 and 1924; the yields per acre were :—

	No Nitrogen.	1 cwt. Sulphate of Ammonia.	2 cwt. Sulhpate of Ammonia.	Increment in Yield for 1st cwt.	2nd cwt.
1923 Oats, bu ...	29·2	37·3	46·5	8·1	9·2
Straw, cwt.	19	26	36	7	10
1924 Barley, bu.	23·9	32·5	42·7	8·6	10·2

In the case of potatoes, however, the second increment in yield is usually less than the first, though the total effect of the higher dressing still remains profitable because of the higher value of the potato crop.

The results have been, in tons per acre :—

	No Nitrogen.	1½ cwt. Sulphate of Ammonia.	3 cwt. Sulphate of Ammonia.	4½ cwt. Sulphate of Ammonia.	Increment in Yield for 1st dose.	2nd dose.	3rd dose.
1923 ...	12·0	13·7	15·1	14·8	1·7	1·4	Nil
1924 ...	8·0	9·5	9·4	—	1·5	Nil	—

The effect of the nitrogenous dressing depends on its time of application. For cereals it has happened that the later dressings, especially when large, have been more effective than the earlier ones (p. 118). For potatoes it has hitherto always happened at Rothamsted that the application of the sulphate of ammonia with the seed has been more effective than the later top dressing when the plants are showing through the ground. Swedes appear to behave in the opposite way. The physiological basis of this problem of nitrogen intake and nitrogenous efficiency is being studied by Dr. Gregory.

CHLORIDES AND SULPHATES AS FERTILISERS.

Farmers now have the choice of muriate or sulphate of potash : and they can also have the choice of muriate or sulphate of ammonia. The experiments with potassic fertilisers are described under " Potatoes." Our experience with the muriate of ammonia is that it is less effective than the sulphate for potatoes but more effective for barley. The difference depends on the rainfall during the months of March, April and May and becomes less as the rainfall increases. The average of all the results at Rothamsted has been as follows :—

	1921	1922	1923	1924
Effectiveness of muriate when that of Sulphate = 100 ... ... Corn ...	106	103	109	104
Potatoes	(112)*	95	92	100
Rainfall—March, April and May (inches)	4·08	7·38	5·64	8·95

*Crop almost failed ; 2 tons per acre only.

The chloride of ammonia has had a remarkable effect on the grain of barley as is described below.

BARLEY.

During the past three years an extended investigation into the effect of manures on the yield and quality of barley has been carried out at Rothamsted and on certain good barley farms in various parts of the country, the work being done in connection with the Research Scheme of the Institute of Brewing. The variety grown is Plumage Archer, and seed from one and the same field was used at all the centres.

The results show a considerable degree of concordance among themselves, but they differ in several important respects from the current teachings of agricultural science. It is usually recommended that the manuring for barley should be mainly phosphatic, nitrogen being given only after a corn crop and potash but rarely. Out of 30 different tests this recommendation would have involved loss of money in no less than 26. The actual yields are given on p. 114; the average reduction in yield in bushels per acre, consequent on the omission of each fertiliser during the three years 1922, 1923 and 1924, has been :—

Decrease due to omission of :—	After a straw crop.	After roots fed off.	After potatoes or beets (well manured).	Mean of all experiments.
1 cwt. sulphate of ammonia ...	5·8	3·9	6·7	5·4
3 cwt. super-phosphate	0·9	[0·5]	1·2	0·5
1½ cwt. sulphate of potash	[1·1]	1·3	1·1	0·3

(The figures in brackets are increases and not decreases.)

The reasons for this unexpected result are probably two :—

1. The modern varieties of high quality barley, such as Plumage Archer, are stiffer in the straw than the older ones, and therefore can carry larger crops of grain without risk of being lodged. Apparently, therefore, they can safely receive more nitrogenous manuring.

2. Good farmers now realise the importance of giving ample dressings of superphosphate to their root crops and sufficient of this fertiliser generally remains in the soil to satisfy the needs of the barley. Potash and phosphates intended for the seeds mixture can, of course, be applied to the barley in which they are sown. The barley may derive benefit, but the profit from these manures must come from the seeds.

One of the distinguishing features of the scheme is that all the experimental barleys are examined by expert maltsters appointed by the Institute of Brewing Research Committee, and are afterwards malted separately and the malts fully analysed.

It is shown that the use of a nitrogenous manure even after roots folded off has not adversely affected the valuation of the barley or the value of the malt, but that the omission of potash from the manure lowered some of the desirable qualities of the malt in 1922, though not apparently in 1923. At each centre the heaviest crops obtainable by manuring have been valued as high, or nearly as high, per quarter, as any other samples of the same set, and it is clear that manurial schemes can be devised which will enhance the present yield without detriment to valuation. So far as the investigation has gone it suggests that farmers using a good modern variety of barley can aim at the biggest crop that will stand, and they can use the appropriate fertiliser to secure this without fear of loss of valuation.

Thus, for the season 1923, the figures for valuation were :—

Valuation per quarter of 448*lb.*, 1923 *barleys* : *made January*, 1924.

	Rotham-sted.	East Lothian.	Eyton.	Chisel-borough.	Walcott.	War-minster.	Lincs. Wolds.
1 cwt. sulphate of ammonia	57/–	49/6	49/–	47/–	41/6	52/–	42/–
No Nitrogen	56/–	49/–	50/–	46/–	41/–	52/–	41/6

A remarkable effect is produced when the chloride (or muriate) of ammonia is substituted for the sulphate. In every instance the valuation of the grain has been raised and its nitrogen content lowered. This is shown by the following table :—

Season.	Valuation of Barley. per qr. of 448 lb.		N. content of grain per cent. of dry matter.	
	Sulphate of Ammonia.	Ammonium Chloride.	Sulphate of Ammonia.	Ammonium Chloride.
1922 ...	31/–	36/–	1·647	1·602
1923 ...	57/–	58/–	1·544	1·485
1924 ...	63/6	64/–	1·517	1·495

The result is all the more interesting in that this is the only manurial method hitherto tested which has consistently improved the quality of the grain. Other treatments have acted sometimes one way and sometimes the other, the change being usually small and unpredictable.

When yield is combined with the valuation and allowance is made for tail corn there is found to be a considerable difference in money value per acre in favour of the chloride :—

Yield (measured bushels per acre) and Money Value of Barley per Acre.

	Sulphate of Ammonium.		Ammonium Chloride.		Difference in favour of Chloride as against Sulphate.
	Yield.	Money Value per Acre.	Yield.	Money Value per Acre.	
1922 ...	36.0	136/–	35.7	156/–	20/–
1923 ...	32.5	239/–	35.6	265/–	26/–
1924 ...	29.8	238/–	29.7	249/–	11/–

In the course of the work it has become clear that the method of valuation commonly adopted does not always work out quite fairly either to the buyer or the farmer. On the loams the estimate has usually been tolerably correct; the value of the malt obtained has paid the cost of the barley, the transport, expenses and profits of malting and other charges. But on the lighter soils, the barley has not generally been as good as it looked, so that the value of the resulting malt did not pay all the charges. On the chalk and limestone soils the barley turned out better than it looked; the farmer received less than he deserved and the malt gave an additional profit to the maltster.

These results are quite intelligible. The buyer judges from certain external appearances of the barley which are on the whole correlated with the value of the resulting malt. But the correlations between the external characteristics and chemical composition are liable to be affected by changes in environment, and it need occasion no surprise that a correlation holding good on loams may be modified in one direction on a sandy soil, and in another on a chalk soil.

The malting and brewing part of the investigation lies outside the scope of Rothamsted, and is carried out entirely by the Institute of Brewing, but the Station, at the cordial invitation of the Institute, is keeping in close touch with the work.

BASIC SLAG AND GRASS LAND.

It is well known that basic slag produces excellent results on many grass fields, especially on the Boulder clays where there is much bent grass and only little wild white clover, but on a number of fields it fails to act.

Two causes of failure are already known, and methods of dealing with them have been worked out :—

(1) The land may be too sour, requiring a dressing of lime before the slag can act.

(2) There may be insufficient potash; this may be supplied by addition of kainit, 20 per cent. potash salts, etc.

All basic slags, however, do not behave alike. Examination shows that they fall into two great groups: those in the making of which fluorspar was used: and those to which no fluorspar was added. Field experience shows that the fluorspar slags are often less effective than the others: chemical examination indicates that they contain some of their phosphate in the form of fluorapatite, a substance having little, if any, value to plants. The slags free from fluorspar, on the other hand, contain some, if not all, of their phosphate in the form of silico-phosphate, which is of very considerable value to plants. Mr. Page has developed a method for ascertaining the amount of fluorine in slags, from which can be calculated the maximum value for the quantity of fluorapatite present. Some of the results are:—

Slag No.	(1) Total Phosphate, per cent. of slag.	(2) Citric Solubility, per cent. of total phosphate.	(3) Fluorapatite (little value) per cent. of slag.	(4) Silico and other phosphates (much value) per cent. of slag.
1	42·5	77·2	1·4	41·1
2	29·2	91·0	Nil	29·2
3	28·9	16·4	26·9	2·0
4	25·1	98·4	Nil	25·1
5	24·3	30·0	22·0	2·3
6	21·1	27·7	12·3	8·8
7	19·8	70·9	Nil	19·8
8	18·0	81·3	1·3	16·7
9	17·8	37·7	17·1	0·7
10	17·2	78·7	1·4	15·7

(1) Total phosphoric oxide (P_2O_5) multiplied by 2.18 to convert into the equivalent quantity of tricalcic phosphate ($Ca_3(PO_4)_2$).

(2) Percentage of the total phosphoric oxide (P_2O_5) which is soluble in the official 2% citric acid solution.

(3) Calculated from fluorine present, assuming all to be in form of fluorapatite.

(4) The remaining phosphate.

The slags are arranged in order of total phosphate and therefore approximately in order of price. Reference to the last column shows, however, that they differ considerably in their content of effective phosphates. Thus slags 2 and 3 are rated equal by the ordinary analysis and might be offered at the same price by a merchant acting in perfectly good faith and honesty. In the field tests No. 3 is less effective than No. 2. Mr. Page's method shows that it may contain most of its phosphorus in the non-effective form of fluorapatite, while No. 2 contains all its phosphates in the effective forms. The citric solubility test discriminates between these slags but its indications are not always very clear. The fluorine method promises to be more helpful.

The new method does not, however, enable the slag to be completely characterised and there are still differences in effectiveness which cannot be explained. Slags No. 1, 6, 7 and 8 were compared in the sheep grazing trials at Rothamsted over a period of four years. The gains in live weight of sheep over those obtained on the unmanured plots have been :—

	1921	1922	1923	1924	Total benefit in 4 years., lb. live weight per acre. Slagged over unslagged land.
Slag No. 7	50	19	62	18	149
,, ,, 8	Nil	Nil	Nil	30	30
,, ,, 6	Nil	Nil	15	Nil	15
,, ,, 1	Nil	21	7	Nil	28

It is obvious that No. 7 is by far the most effective of these slags, being better even than No. 1 which was known to act well on other soils, but no chemical test so far tried would show this superiority to a prospective purchaser. At the time we obtained the slag neither the makers nor ourselves knew or even suspected that it would prove any better than No. 8 or as good as No. 1, nor can we yet explain why it should be so. It seems clear that somewhere in its history this slag received some treatment which, if it could be repeated on other slags, might greatly enhance their agricultural value. A possible clue has been furnished by the manufacturers and an observation has been made in the chemical laboratory which may furnish the solution of a very attractive problem.

A third important chemical factor has been discovered during the past season by Dr. Brenchley and Mr. Page. Some of the slags examined were found to contain substances harmful to the plant. This does not, of course, mean that they actually damaged the crop : what happened was that in these particular slags the beneficial effect of the phosphate present was in part counteracted by the harmful substance. All these problems are being followed up and the co-operation of the slag makers is secured through the Permanent Basic Slag Committee of the Ministry of Agriculture. In the meantime farmers who have applied slag to their grass and obtained disappointing results are requested to communicate the facts to the Director.

POTATOES.

The experiments with the different potash manures begun in 1921 have been continued (p. 120). The muriate and the sulphate of potash behave nearly but not quite alike, the muriate giving sometimes a slightly better and sometimes a slightly less yield than the sulphate. The determining factor is partly rainfall, the sulphate tending to give the higher yield in drier conditions and the muriate in wetter, but there is something beside this, for in 1924 the sulphate came out the better in spite of the wetness of the season.

Addition of other chlorides (*e.g.,* salt) to the muriate, is, however, injurious; neither kainit nor sylvinite gave the full benefit expected from the potash because of the harmful effect of

the salt. This is to some extent mitigated by additions of dung, but the crop always falls below that obtainable from the muriate or the sulphate. The results at Rothamsted are :—

YIELD OF POTATOES WHEN SULPHATE OF POTASH IS USED = 100.

	1922		1923		1924	
	Without dung.	With dung.	Without dung.	With dung.	Without dung.	With dung.
Muriate of Potash	106	98	98	105	98	99
Sylvinite	89	—	87	84	108	105
Rainfall (March-May inclusive).	4.08		5.64		8.95	

These fertilisers affect the quality of the potatoes. Of the complete manured plots, those receiving sulphate of potash produce tubers with the highest percentage of dry matter.

Potassic Fertiliser Used.	Percentage Dry Matter of Potato Tubers.				
	Rothamsted. 1922	Rothamsted. 1923	Reaseheath. 1922	Seale-Hayne. 1922	Usk. 1923
Sulphate ...	24·26	21·73	21·68	24·4	23·6
Chloride ...	22·02	20·85	19·63	22·3	22·5
Low Grade Salts	19·68	17·87	17·28	22·7	21·0
No Potash ...	23·07	20·65	17·62	25·7	22·1

The tubers grown with low grade potash salts (kainit, sylvinite) are the lowest in dry matter content, coming out even below those grown without potash.

The percentage of starch in the dry matter is an important quality factor, and in all tubers so far analysed the value comes out higher for the sulphate of potash than for any of the other salts.

Potassic Fertiliser Used.	Yield in tons per acre.	Dry Matter per cent. in Tubers.	Starch per cent. in Dry Matter.	Starch. Tons per acre.
Sulphate	8.30	24·26	65·84	1·325
Chloride	8·32	22·02	64·00	1·175
Low Grade Salts ...	8·06	19·68	58·20	0·925
No Potash	2·47	23·07	57·16	0·325
Control	2·98	23·36	58·20	0·405

Magnesium sulphate continues to give interesting results; its effect on potatoes has been beneficial at several centres though we cannot yet explain why.

Complete Artificials.	Rothamsted. 1922 No Dung.	Rothamsted. 1923 No Dung.	Rothamsted. 1923 Dung.	Blaydon. 1922 No Dung.	Blaydon. 1922 Dung.	Walbottle. 1922 No Dung.	Walbottle. 1922 Dung.	Newton Abbot. 1922 Dung.
No Magnesium Sulphate ...	100	100	100	100	100	100	100	100
With Magnesium Sulphate ...	102	104	104	108	114	118	129	117
	97	108	104					120

GREEN MANURING.

The importance of increasing the amount of organic matter in the soil is widely recognised, and experiments have been carried out at Rothamsted for some years to determine the best ways in which this could be done. Mr. Page has been studying green manuring, and he has now been able, thanks to the intervention of the Research Council of the Royal Agricultural Society, to arrange for a number of experiments at outside centres, and thus to obtain direct information on the extent to which soil and climatic factors influence the method.

In practice two kinds of green manuring are possible, though they are not always practicable :—

1. Summer catch crops may be turned in before the winter corn.
2. Winter catch crops may be turned in before roots.

In general, the first method can be practiced only on fallow land, early ploughed seeds leys, or land that has carried a crop harvested early, such as a silage or soiling crop. The eastern counties appear to offer the best opportunities for success.

Trials of this method, using mustard as the green crop, are in progress at six centres, one in the west (Gloucestershire), and five in the east (Kent (2), Suffolk, Beds. and Northants.). The results of the test at Rothamsted give a forcible illustration of its value. Mustard was sown on the bare fallow after cleaning on 20th August, 1923. It was turned under on October 18th, and winter oats were drilled at once. The yields of oats in August, 1924, were as follows :—

Basal Manure.	Yield of Oats, bu/acre.		Increase due to Mustard.	
	After Mustard Ploughed in.	After Fallow (no mustard)	Bu.	Per cent.
None	43·3	25·0	18·3	73
5 tons town refuse	51·8	27·1	24·7	91
10 ,, ,, ,,	49·3	30·6	18·7	61
Average	48·1	27·6	20·5	74

The turning in of mustard thus added, on the average, 20 bushels per acre to the crop. The cost per acre for mustard seed and the extra operations involved in drilling and turning under amounts to 18/-, whilst the increased yield of oats was worth 79/6 per acre, without reckoning the value of the extra 9 cwts. of straw per acre.

The turning in of winter catch crops before roots is probably of even greater practical importance. Climatic factors play a great part since the green crops have to pass through the winter : if this is too cold, crops sown in the autumn do not usually make sufficient growth, by the time when the land needs to be prepared for roots, to produce any marked effect on the root yield. It is probably only within the region, with an average winter temperature exceeding 40° F. and an annual rainfall between 30 and 40 inches, that the present set of autumn sown green crops can as a rule be successfully grown for turning under

in the spring before the roots. The fact that the corn harvest is earlier in this part of the country, so that green crops can be sown earlier, also helps. Outside of this region autumn sown green crops do not in general make enough growth by the spring to be useful for green manuring purposes; this has happened at Rothamsted for three successive seasons (1921-1924).

The problem therefore arises of finding a system of green manuring for roots which is applicable to the colder northern and eastern districts.

Undersowing of green crops in the corn, and possible new crops are being tried: and at certain centres the relative economic values of folding the green crops to sheep, and of turning them in for manure, are being ascertained.

THE LEGUMINOUS CROPS.

Considerable attention has been devoted to the leguminous crops, owing to their great importance in the rotation and as stock foods. The effect of manures applied to the barley on the clover sown in is shown on pp. 114, 115. Sulphate of ammonia had no bad effect on the clover although it increased the yield of barley. We have met cases where the application of sulphate of ammonia to barley reduced the yield of the clover, but in our experience this happens only when the land badly needs lime, and it is attributable to the increased acidity which sulphate of ammonia is liable to produce on such soils. The phosphate apparently had no action while the potash exerted a distinct residual effect, giving an additional 6 cwts. of clover hay in 1924 and 12 cwts. in 1923. The results indicate that potash should be applied to the clover if the barley crop has been good, unless it has already been given to the barley.

Inoculation of leguminous crops, especially lucerne.

Ever since 1890, when Hellriegel and Wilfarth discovered that leguminous plants live in association with micro-organisms inhabiting the nodules on their roots, efforts have been made to improve the growth of leguminous crops by adding the appropriate organisms to the soil. Some successes were obtained on the Continent, but the method failed in this country; the results at Rothamsted in 1906 and 1907 were not then considered sufficiently good to justify extension to farm practice.

There is no doubt, however, that for certain crops the principle is sound; the failure of inoculation in Britain must be attributed to the lack of compliance with the conditions necessary to success. During the past three years the whole subject has been re-examined in the Bacteriological Department.

The subject affords an admirable illustration of the way in which a practical problem of great importance remains unsolved, in spite of many empirical efforts, until the underlying principles have first been studied and a solid groundwork of definitely ascertained facts has been obtained.

The failure of inoculation in many cases has been traced to the circumstance that the organisms were already present in the soil, but some condition essential to the growth of the plant

was not realised, and the deficiency could not be remedied by merely adding more of the organisms.

Further, it was shown that many of the cultures sent out to farmers died on the way, so that the material used for inoculation was useless. This difficulty has been overcome by devising means whereby the organisms could be transported alive. The need for fresh, active stocks of the organisms available for farmers at short notice has been met by devising a medium in which the organisms grow much more quickly than in the older media.

The organism cannot flourish in soils having too great a degree of acidity; a usual limit corresponds with the pH scale number 6.0.

A much more difficult problem is being attacked in the Bacteriological Department. The organisms were found to pass through a life cycle including motile stages in which they can travel to the plant, and non-motile stages in which they cannot. The non-motile stage can, however, be made to change into the motile stage by certain treatments, especially the application of phosphates; this is no doubt one reason for the remarkable effect of basic slag in increasing the growth of clover on certain soils. Messrs. Thornton and Gangulee have measured the time required for the organisms to assume the motile form in the soil, and the rate at which they then spread through it. On the basis of these various facts, Mr. Thornton has been able to devise a method of inoculating which ensures an earlier commencement of spread of the organisms in the soil, and therefore a better chance of infection of the roots, than in any method previously tried in this country.

The Research Committee of the Royal Agricultural Society has made a grant to Rothamsted which is allowing extensive trials to be carried out at some thirty centres scattered throughout England to test the value of the method for lucerne. It is too soon to speak definitely about the results, but already inoculation has proved of considerable value in new districts where the crop has not previously been grown, and it has in places doubled the growth in the first year as compared with the uninoculated plots, besides giving vigorous plants which promise to survive and come out in full strength in the summer. Meanwhile the purely scientific study of the organism and of its relation to the plant is being steadily pursued with the object of getting further information. Exceptions and difficulties will inevitably arise as soon as farmers adopt inoculation as a general practice, and the surest way of minimising the resulting losses and inconveniences is to obtain the fullest possible knowledge of the whole process.

Two investigations have been carried on which cannot fail to have important bearings on the practical problem. The first, which is still in hand, is concerned with the influence of straw on the formation of nodules. Attention was directed to this by the observation that farmyard manure is more effective in increasing the growth of clover than any dressings of artificial manures

yet tried. In pot experiments unrotted straw greatly increased the numbers of nodules formed on each plant; there was, however, no increase of yield till phosphates were added. A dressing of straw and phosphate has been found in field tests to be an effective fertiliser for beans and affords a method of increasing the organic matter of the soil which might find useful application in practice.

The second investigation brings out the fact that the plant is just as important as the organism in the partnership. It arose as a result of Miss Warington's important discovery that many leguminous plants fail to grow unless supplied with traces of boron. Dr. Brenchley and Mr. Thornton, taking the broad bean as their example, showed boron to be essential to the proper functioning of nodules on its roots. In the normal course, conducting vessels grow out from the vascular system of the plant root and enter the nodule. Along these vessels food materials are brought from the plant to the bacteria, and the products of their activity are carried back to the plant. The vessels thus act as conduit pipes, connecting the organisms with the plant and making the partnership effective. In the absence of boron these vessels do not form or are very weakly developed. The organisms, losing their normal source of food, become parasitic and destroy the plant protoplasm, being then harmful instead of useful to the plant. The work thus shows that the organism is a potential parasite; only by the nice adjustment occurring in the healthy plant can the beneficial partnership be maintained.

In most soils there is apparently sufficient boron to allow of full development. But instances are on record in Japan, and possibly elsewhere, where peas, which do not need boron, will grow while other leguminous plants which need it will not. In these soils there might be a boron deficiency. The more important result emerges that the successful growth of a leguminous crop depends on three conditions: presence of the proper organisms and soil conditions necessary for their growth; the proper nutrition of the plant; and development of the conducting system linking the organisms in the nodule with the circulating system of the plant.

Liming.

The effect of lime on sour arable land and on certain kinds of grass land is well known and farmers are frequently advised to use more of this substance. But directly they begin to follow the advice they are faced with the difficulty that analysts cannot as a rule inform them just how much lime per acre they should apply, and a round figure of one or two tons per acre is often suggested. The recommendation suffers from the defect that no farmer can afford to supply two tons per acre if one ton is sufficient, apart from the consideration that too large a dressing may injure the crop or the soil.

Various empirical methods have been devised from time to time to give some idea of the quantities needed, but the different tests give different results, and in absence of definite knowledge

as to how they act or what they really indicate, it is impossible to arrive at any satisfactory conclusion.

The method hitherto used in this country was devised in 1913 by Drs. Hutchinson and MacLennan in these laboratories. It has served a useful purpose, but it suffers from the drawback that it is considerably affected by three soil factors, none of which it accurately measures: the hydrogen ion concentration: the "buffer action": and the neutral salt action in the soil. These are separated in the modern electrometric method used by Mr. E. M. Crowther in the Physics Department. The older method, however, has the merit of convenience, and it has now been improved by the introduction of certain empirical corrections.

Measurements at Rothamsted and at Woburn have shown that the effects of soil acidity induced by long-continued and excessive use of sulphate of ammonia are manifested as far down as 3 or 4 feet in the soil, and are not confined to the surface 9 inches.

Soil Chemistry, Physics and Microbiology.

In the Chemical Department work has been done under Mr. Page on the organic matter of the soil, which plays so important a part in soil fertility. Mr. du Toit has adduced evidence that humus is formed from lignin and not from the carbohydrate materials, cellulose, etc., to which its origin was formerly assigned. It is true that these substances can be made in the laboratory to yield black products looking like humus, but chemical examination shows that only the lignin product closely resembles the substance actually present in the soil. The problem is difficult and necessitates much further study, but the information is needed in order to discover what are the useful organic constituents of the soil. It is expected that this work will find application to green manuring.

Another important line of enquiry is in connection with the bases in the soil. It is shown that many of the important soil properties depend on the presence of a complex calcium combination: indeed, of all elements in the soil, calcium is probably the chief in agricultural significance. This calcium can be replaced by hydrogen under conditions of high rainfall: the soil then readily becomes acid. Alternatively it can be replaced by sodium in dry regions where irrigation water containing sodium salts is used (as not infrequently happens). The sodium combination differs chemically and physically from the normal calcium combination, and it is infertile when treated by the normal agricultural methods: it might conceivably be fertile if treated by methods specially suited to its properties. But its gravest defect is that it is easily hydrolysed, forming sodium carbonate, a very serious plant poison. Or, again, the calcium may be wholly or partially replaced by magnesium or potassium. Each of these products behaves unlike the calcium product when subjected to ordinary treatments and therefore is regarded as infertile. This new knowledge will undoubtedly prove useful in devising means of dealing with difficult soils: the Weald and Lower Lias clays deserve study from this point of view.

SOIL TILTH AND CULTIVATION.

In the Physical Department the studies of tilth under Dr. Keen are being continued. The work includes exact laboratory studies of the physical factors involved in tilth and also measurements of the drawbar pull when land is ploughed under varying conditions. An investigation of this kind is prolonged but already interesting results are emerging. The purpose of the laboratory work is to develop the science of soil physics on which ultimately a scientific soil cultivation can be based, just as scientific manuring is based on chemistry and plant physiology. Mr. Haines has completed some important pioneering work on the physical properties directly concerned in ploughing: cohesion and plasticity of soil, and surface friction between soil and metal. But in order to get very far with the investigation it is necessary to study the underlying causes, and so researches are carried out which, while less obvious in their bearing, are no less, but possibly even more, essential than those just mentioned. Good tilth in soil is traditionally associated with the formation of compound particles or soil aggregates. These in turn are determined by the colloidal properties of the soil: and so it comes about —as often in agriculture—that progress in a practical problem cannot be made until some abstruse and apparently wholly irrelevant scientific problem is solved. The friction between the plough and the soil is a practical problem of the first importance: but it cannot be adequately studied without a proper understanding of the colloidal properties and the ultimate constitution of the soil. The three methods of investigating these in the Physics laboratory are:—

(*a*) A study of the relative intensity of the forces holding soil particles together when the soil has been subjected to a variety of treatments that simulate field conditions. The method adopted is the measurement of the amount of soil in suspension after shaking with water under definite conditions;

(*b*) Direct measurements of the vapour pressure at different moisture contents of soils treated in various ways;

(*c*) Indirect measurements of the vapour pressure using a method that depends on the lowering of the freezing point depression of benzene in contact with the moist material that has an affinity for water.

The results show that many of the observed properties of soils can be interpreted on the assumption that the colloidal material is permeated with minute capillaries, analogous to those investigated by Zsigmondy and Anderson in silica gel. They also indicate that compound particles are formed in soil at comparatively high moisture contents, and that once formed they are not easily disintegrated. This last conclusion has led to a somewhat disconcerting discovery. It is found that complete dispersion of soil is frequently not attained in the standard method of mechanical analysis: hence many of the recorded

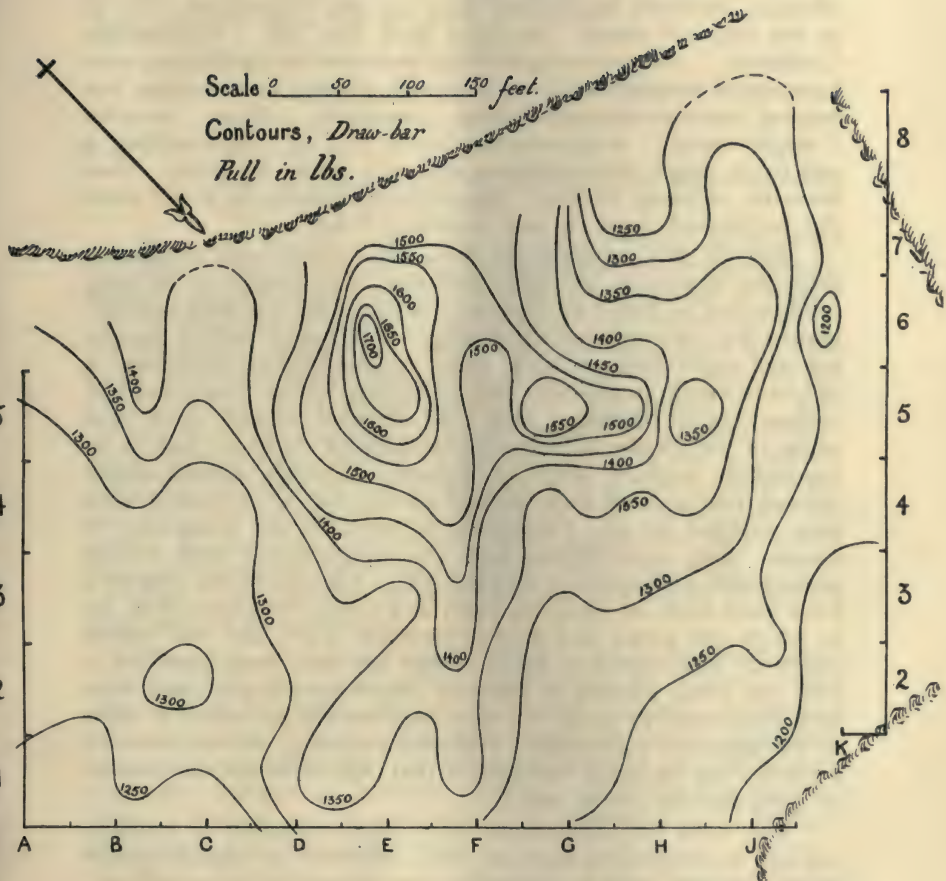

FIG. I.—Diagram showing the variation in drawbar pull over an area that to visual inspection appeared uniform.

data are erroneous. Nor is dispersion complete in the standard dilution method for counting soil organisms, and the results of any given plating are liable to the error of counting as a single organism a group or colony on an undispersed soil aggregate.

A further consequence of great interest to the expert has also emerged : certain of the so-called " constants " of the text books, such as the Hygroscopic Coefficient, the Wilting Coefficient, Moisture Equivalent, etc., are not " constants " at all in the physical sense. Dr. Puri finds that the " Hygroscopic Coefficient " (the percentage of soil moisture in equilibrium with a saturated atmosphere) is so inherently difficult to determine that marked discrepancies are almost inevitable. These so-called " single value " measurements which aim at characterising a soil by a single determination are very liable to error. One, however, is being studied : the moisture content of a soil when the well-mixed mass is just becoming sticky.

But all this fundamental work takes time, and meanwhile there are important practical problems for which a working solution can be found by empirical means. On the field side Mr. Haines has obtained further readings of drawbar pull in ploughing and cultivating, as done under ordinary farm conditions, a criterion which necessitates the dovetailing of the work into the ordinary farm routine. This year detailed studies have been made of the causes of the irregularities of drawbar pull in an apparently uniform piece of ground. Careful measurements showed that a level field uniform to the eye which would have been selected by any Committee as suitable for ploughing or tractor trials nevertheless had soil irregularities that caused considerable differences in drawbar pull. The results for Sawyer's Field have been set up in the form of a contour diagram (Fig. 1), in which the peaks and ridges represent high, and the valleys represent low, drawbar pulls. Had the field been used for a test, the areas allotted to different implements might have been very favourable to some and very unfavourable to others in spite of the apparent uniformity. Methods are being devised whereby a survey can be made beforehand that will show the distribution of irregularities in the soil.

The work has also shown how much reduction in drawbar pull can be effected by applying lime, limestone or organic matter to the soil, and how to obtain the best effects by these methods. Further, it has been found that the friction of ploughing can be reduced by an electric device simple in principle and only awaiting exploitation to become important in practice.

Much work is done in the Physics Department in studying the moisture relationships of the soil. Measurements conducted in large cylinders filled with Rothamsted soil show that little water rises to the surface from the subsoil when the ground water falls to 4 or more feet below the surface. A definite relation was found between the potential evaporating power at the surface and the change in ground water level. This work will be greatly facilitated when the continuous recording devices now being devised are installed.

THE MICRO-ORGANISMS OF THE SOIL.

Reference has been made in previous Reports to the important part played by the soil micro-organisms in determining the productiveness of the soil. These organisms break down the organic matter in the soil, the plant residues, farmyard manure and other organic manures, converting them into useful plant foods. They effect at least three kinds of action which are directly beneficial to the plant :—

1. The production of nitrates.
2. The decomposition of plant material producing structureless compounds having valuable colloidal properties.
3. The decomposition of intermediate products which would be toxic to plants.

The most striking result brought out by recent observations has been the fluctuation of the micro-organisms in natural field conditions. There are two-hourly fluctuations, recognised at present only in the case of bacteria, which have been measured in the Bacteriological Department. Superimposed upon these are daily fluctuations which are known to affect not only bacteria but protozoa also, the level of numbers for any species at 9 a.m. varying from day to day. Further, there are seasonal fluctuations; a great rise in spring, a fall in summer, a rise in autumn, and a fall in winter; bacteria, protozoa and apparently also algae and fungi being affected. It is not known whether there are annual fluctuations, though this would appear not improbable. The phenomena are not confined to soil micro-organisms; similar fluctuations are recorded for plankton and pond algae, though the data are not so complete.

The cause of the daily and probably of the hourly fluctuations of bacteria is fluctuation of the number of the amœbæ which feed upon them. Why the amœbæ should fluctuate was for long a mystery; Mr. Cutler and Miss Crump have thrown some light upon it by showing that rate of reproduction of amœbæ depends upon the number of bacteria present; when the bacteria fall below a certain level no division of the amœbæ occurs; it begins only when they rise above this.

The spring and autumn increases in number, however, affect bacteria and protozoa alike, so that some other cause is apparently operating.

All this work has been possible through the elaboration by Mr. Cutler of methods of counting protozoa in the soil, and the development by Mr. Thornton of a plating medium in which bacterial colonies would develop uniformly and without the spreading which in the older technique suppressed some of the slow growing forms. The medium has the further advantage of being prepared from pure substances so that it can be reproduced with precision whenever desired, and it has thus been possible to apply a statistical formula whereby the degree of accuracy of the plate counts can be estimated.

The quantitative measurements give a much clearer picture than was hitherto possible of the character of the soil population. The average numbers obtained in the high activity period of spring and the low activity period of the winter are as follows :—

			Numbers per gram of soil.	Approx. weight. lbs. per acre.
Bacteria	High Activity	...	45,000,000	50
	Low ,,	...	22,500,000	25
Amoebae	High Activity	...	280,000	320
	Low ,,	...	150,000	170
Flagellates	High Activity	...	770,000	190
	Low ,,	...	350,000	85
Ciliates	High Activity	...	1,000	—
	Low ,,	...	100	—

The weight (also the volume) of the protozoa in the soil considerably exceeds that of the bacteria in spite of the high numbers of the latter.

It is more difficult to ascertain whether the production of plant food fluctuates in the same way as the numbers of organisms. There are undoubted fluctuations, but more data are required before the proof becomes as rigid as it is for bacteria.

There is definite evidence that crops obtain only part of the possible food supply, much of the rest being taken by soil organisms and thus rendered unavailable. One cannot as yet say which are the worst offenders in this respect; at present suspicion attaches to the algae, and the laborious task of clearing up the problem is being carried out by Dr. Bristol Roach.

CONTROL OF THE SOIL ORGANISMS.

The knowledge of the soil organisms gained in our laboratories is allowing of a steadily increasing degree of control. There are at present four directions in which large scale tests are carried out.

1. Inoculation of lucerne by the appropriate micro-organisms.
2. Conversion of straw into a useful manure by the cellulose decomposing organisms.
3. Control of the plant food production process by partial sterilisation methods.
4. Control of plant disease organisms by similar methods.

Of these, inoculation has already been discussed on p. .

Artificial Farmyard Manure.—The production of manure direct from straw is now being carried out on the large scale. In the past season no less than 3,000 tons of straw and like material were treated in Britain alone in addition to much larger quantities treated abroad.

The method of making artificial farmyard manure is based on the facts that the necessary organisms are already present and need only suitable conditions to call forth their

activities. Food stuffs (especially nitrogen compounds and phosphates) are supplied, along with calcium carbonate to obviate acidity, and decomposition then proceeds rapidly, converting waste useless straw and other materials into valuable manure.

The large scale development is carried out by the non-profit making "Adco" syndicate, of which Lord Elveden is Chairman, thus relieving the Station of much exploitation work for which it is not suited. The numerous scientific problems constantly arising out of the field experience are studied by Messrs. E. H. Richards and R. L. Amoore in these laboratories.

The organisms are naturally present in the straw or in the dust and they need not be deliberately added. It is, however, important to discover exactly what they use, how they do their work, and what conditions are necessary to their efficiency. These problems are studied in the Bacteriological Department. A new organism has recently been found by Mr. P. H. H. Gray, which not only decomposes cellulose rapidly, but unlike the *Spirochæta Cytophaga* previously isolated in the laboratory, acts in presence of sugar and is indeed stimulated by small quantities of xylose and lignin such as occur in straw. It seems probable that this new organism plays a considerable part in the decomposition of straw in practice, in the making of farmyard manure and other important changes.

PARTIAL STERILISATION AND CONTROL OF SOIL PESTS AND DISEASE ORGANISMS.

These are conveniently dealt with together. The methods first tested in these laboratories 17 years ago involved either heating the soil or treatment with volatile antiseptics such as toluene and carbon disulphide. The first applications were made in glass houses, and the method first used in practice was heat. This is effective but costly, and it cannot be much cheapened. Chemicals offer much better prospects and search is being made in Mr. Tattersfield's Department for agents which will effect the same purpose as heat at less cost. The obvious method of utilising industrial waste products is less useful than might be expected owing to their variable composition: the first investigation is, therefore, directed to the discovery of the organisms to be put out of action and the testing of chemical compounds in a definite systematic manner, so as to obtain information as to the relationships between chemical constitution and effectiveness. The proper quantity and the suitable time and method of application have all to be determined by direct trial, while laboratory experiments are made to discover more particularly the precise actions going on. The most interesting result thus far obtained is that organic substances, such as the cresols, phenol and cresol derivatives, and the chlornitro derivatives, such as chlorpicrin and chlordinitrobenzene, can, when applied to soil in proper quantity, determine substantial crop increases, though it is not yet known how far the effect is due to removal of disease organisms, and how far to improvement in nitrate production or to direct stimulation of the plant. Under this treatment tomatoes

under glass gave no less than 5 additional tons of fruit per acre, worth between £250 and £300.

Some of the substances are solids and are easily handled and applied. The significance of the advances made in recent years in these laboratories will be appreciated when it is recalled that the first agents used were highly inflammable substances, difficult and expensive to transport, and that they were applied to the soil at the rate of 10 tons per acre by means of a special injector—another difficult and costly process. These dangerous liquids were soon replaced by a crude cresylic acid (called carbolic acid), an oily liquid watered into the ground at the rate of 2½ tons per acre—but the process was still expensive, the material alone costing over £160, while the labour was considerable. The new substances are solids, and are so potent that 2 cwt. per acre has proved effective. Although they are not as yet on the market, there seems no reason why they should not be made as intermediate products in connection with one of the large organic chemical industries, such as the making of dyes. It is essential to success that the added substances should be removed from the soil as soon as their work is done, otherwise they may injure the plant: this removal is accomplished by a perfectly natural process. Although the compounds are so poisonous to certain undesirable organisms, they serve as food and energy materials to others among the remarkable population of the soil—an illustration from the lowliest type of life of the old adage: "What is one man's meat is another man's poison."

Among the phenol destroying bacteria one has been found by Mr. Gray to possess the interesting property of converting indol into indigo—a change of great biochemical interest.

The laboratory studies of the effects of partial sterilisation on the soil micro-organisms have been continued by Mr. Cutler and Miss Dixon, using heat and phenol as the two agents; application of either results in an increase in the numbers of bacteria and the destruction of active protozoa, but the course of events is not the same in the two cases. Phenol induces rapid multiplication of specialised types of bacteria capable of using it as a source of energy, but the general bacterial population undergoes little change. Moreover, when applied in small quantities, the phenol does not kill the protozoan cysts; these remain dormant until it has disappeared, and then resume their active existence. A temperature of 65° C. causes the complete destruction of protozoa and an initial depression of the bacteria. Subsequently the bacteria increase and attain high numbers which are kept up for long periods.

It has been found that this partial sterilisation effect takes place within relatively short ranges of temperature; 55° C. or less does not bring it about, but 65° C. gives a result as marked as that of higher temperatures. It is worthy of note that 65° C. is the death point for soil protozoa.

An interesting problem has arisen as to the effect of storage of the soil in bottles or open jars on the soil population. When soil is taken from the field, and after sieving placed in bottles,

the numbers of both bacteria and protozoa decrease rapidly for the first two or three days, after which there is a slow but steady fall for periods exceeding three months. No explanation can as yet be offered.

Wart Disease of Potatoes.—An important case of control of a soil micro-organism has been investigated by Dr. Brierley, Mr. Crowther, Miss Glynne and Mr. Roach. Wart disease, one of the worst potato troubles in this country, is caused by an organism having a remarkable power of persisting in the soil so that it cannot be eliminated by the ordinary method of ceasing temporarily to grow potatoes. The direct method of studying the effect of various chemicals on the organism is inapplicable owing to the difficulty of germinating the winter sporangia: pot experiments failed owing to difficulties of obtaining infection in pots, till Miss Glynne showed how this could be brought about. Direct field experiments were the only satisfactory method of procedure, and these, while tedious and costly, showed that heat (which owing to obvious practical difficulties was tried only in pot experiments), formaldehyde and sulphur were all effective in dealing with the disease. Heat is too expensive, so also is formaldehyde at present, and possibly for a long time to come, but sulphur is relatively cheap. Mr. Roach overcame the earlier failures by using the Simar cultivator, and so ensuring a better mixture of the sulphur with the soil. There is evidence that on light soils, such as are generally used for potatoes, an application of 12 cwts. per acre of sulphur eliminates wart disease. A large scale trial is now being made to test the practicability and effectiveness of the treatment. Heavier soils apparently require bigger doses of sulphur.

On the other hand, it does not appear that the "scab" of potatoes caused by the fungus *Spongospora subterranea* is amenable to treatment by sulphur, although in America, positive results are said to have been obtained.

INSECTICIDES.

The Staff of the Department of insecticides, fungicides, and partial sterilising agents, under Mr. F. Tattersfield, have for the past three years been engaged in a search for a substitute for nicotine. The seeds and leaves of a tropical plant, *Tephrosia vogelii*, have been found to possess approximately the same toxicity as nicotine; these could readily be obtained should the need arise. Special attention has been directed to the possibility of using synthetic substances, since these can be made to any desired standard of purity, and in any quantity. The work is done on systematic lines, the effects of the various groups being studied as they are substituted in a relatively simple molecule such as benzene. Thus it is found that the introduction of a nitro (NO_2) group into the benzene molecule considerably increases the toxicity, while the methyl (CH_3) group has less effect than any of those tested, the order being :—

$$NO_2 > NH_2 > OH > Cl > CH_3$$

When two or more groups are introduced into the molecule the toxicity is much affected by their relative positions in the ring (see p. 66). Several of the substances finally obtained are highly toxic both to insects and eggs; some are being tried this year on a field scale.

This investigation, like that on partial sterilisation, raises the important problem of exploiting a laboratory discovery and applying it on the large scale. Between the Rothamsted Station and the agricultural and horticultural industries there is the important difference that the one is working with a few pounds only, while the other may require in the aggregate thousands of tons. It is not possible for the Research Station to bridge this gap, nor to carry up to the farm stage the methods it may evolve. When superphosphate was discovered at Rothamsted many years ago, Lawes completely separated the factory and exploitation sides from the Rothamsted experiments. In a letter to the Ministry of Agriculture, published in the Journal of the Ministry of Agriculture, February, 1922, Lord Elvedon emphasised the lack of bridging agencies, and offered himself to finance a non-profit making syndicate for the exploitation of the "artificial farmyard manure" process (see p. 32). This is proving a very effective way of securing development. Both the insecticide and partial sterilisation work are now almost ripe for extension to the factory, as also is some of the physical work described above. The most suitable procedure has yet to be decided.

PLANT PATHOLOGY.

New laboratories have been erected, to which in September, 1924, the Entomological and Mycological Departments migrated; work is now being done under eminently satisfactory conditions.

In the Entomological Department Dr. Imms has concentrated the attention of the Staff on insecticides, on aphids and on the gout fly of barley. The work on insecticides has already been described (p. 35).

Dr. Davidson's aphid studies have shown the important connection between the nutrition of the host plant and the rate of multiplication of the insects; contrary to general belief, it is the best nourished beans on which the aphids multiply most rapidly.

Certain varieties of field beans are only slightly susceptible to aphid attack, and plant breeding experiments suggest that this factor can be transmitted to new varieties. It appears possible, therefore, that a bean might be evolved of commercial value, and, at the same time, possessing considerable resistance to aphid attack. No rapid progress towards the production of such a variety can be expected owing to the laborious nature of the work and the necessity of making detailed tests at every stage.

A pure line of the bean aphis has been carried on continuously since 1920, over 80 generations having been passed through. The sexual cycle appears with remarkable regularity during early

October in each year. The production of the sexual forms goes on until the following May. If, however, a temperature above 70° F. is maintained, asexual reproduction only occurs, suggesting that the change from the asexual to the sexual method of reproduction is directly influenced by temperature.

The gout fly investigation made by Mr. Frew arose out of a field problem. It was found that couch grass is the chief winter host, and that certain manures, especially farmyard manure and superphosphate, enable the barley plant to escape damage by inducing early growth of the ear out from its ensheathing leaves. Once the plant is infestated, however, nothing can be done : preventive measures only are possible, and of these, early sowing and suitable manuring are the most important.

In the Mycological Department, the chief work has been the study of wart disease in potatoes by Dr. Brierley, Miss Glynne and Mr. Roach, and the commencement of an investigation into mosaic disease of plants by Dr. Henderson Smith. Reference has already been made to the discovery that a dressing of finely powdered sulphur at the rate of 12 cwts. per acre intimately mixed with the soil greatly reduces, and probably eliminates, the disease from light soils. Another practical application of the work results from Miss Glynne's discovering how to infect susceptible varieties with the disease. At present the only method of testing the immunity of new varieties is to grow them for a year or more on badly infected soil. By using Miss Glynne's method described on p. 66 it is possible to discriminate between susceptibles and immunes in a few weeks, a matter of great importance to the plant breeder.

The work on mosaic disease started with the discovery by Dr. Bewley of the Cheshunt Experimental Station of nodules containing certain organisms which appeared on tomato-extract culture-media inoculated with juice of plants suffering from this disease. The work already done indicates that similar nodules may arise on these media when inoculated with other organisms not connected with mosaic disease; but that they also occur readily (perhaps more readily) after inoculation with certain organisms obtained from mosaic-diseased plants. Dr. Henderson Smith is in touch with the members of the Committee on Foot and Mouth disease, there being points of similarity in the two enquiries.

It has already been stated (p. 32) that algae apparently play a part in the highly important nitrogen cycle of the soil; the study of these organisms is carried out in the Mycological Department by Dr. Bristol Roach. The work has necessitated the isolation in pure cultures of a number of species of algae from the soil and the growth of these organisms on artificial media in order to discover some of their physiological properties. Dr. Bristol Roach has been able to show that most algae grow better in presence of small quantities of certain soluble carbon compounds than when they are completely dependent on carbon dioxide in sunlight for their source of carbon; the exact order of preference for these substances varies with the particular species.

In addition to this qualitative work, Dr. Bristol Roach has introduced exact methods. She has studied quantitatively the growth of a single species in nutrient solutions differing only in the nature of the carbohydrate present, the substances tested being the sugars (pentoses, hexoses, disaccharoses), also mannite and glycerol. The rate of growth of the algae in culture, as measured by the increase in bulk, is constant under uniform favourable conditions for about the first ten days after inoculation, and parallel cultures have equal growth rates within the limits of experimental error. It has therefore been possible to devise a method for growing the alga under constant conditions of temperature, light and aeration, and by taking daily measurements of its bulk to ascertain the rate of growth in the presence of the various compounds under investigation. In this way figures have been obtained for a number of the sugars which can be regarded as representing their relative values as energy sources for the organism concerned. Without this physiological work it is impossible to ascertain with certainty the part played by the algae in the important changes going on in the soil.

STATISTICAL CONTROL OF THE FIELD AND LABORATORY OBSERVATIONS.

It is one of the distinguishing characteristics of the recent Rothamsted work that the field and laboratory observations are, wherever possible, subjected to close scrutiny in the Statistical Department, with the view of estimating the degree of probability attaching to the results, and of indicating modifications in the plan of the experiments that may increase their accuracy. The field data are examined in order to trace correlations between weather, crop growth and other of the quantities measured, the mass of the data being so great that no other procedure gives equally useful results.

As a preliminary, Mr. Fisher found it necessary to develop adequate statistical methods for the study of field data. This work has now progressed considerably.

The methods of experimentation have been closely examined and improvements introduced which allow of a far higher degree of accuracy than could previously be attained.

The difficulties of the older methods of field experimentation arose from uncontrollable variations in the weather and the soil. Experiments repeated on the same soil in different years give discrepant results owing to the variation of the weather; while experiments repeated on different land in the same season give equally discrepant results owing to the variation of the soil. In consequence, even well conducted field experiments suffered from errors of the order of 5 or 10 per cent., a range of inaccuracy too large to meet the requirements of the practical farmer, to whom a difference of 5 per cent. in his average gross yield may make the whole difference between profitable and unprofitable farming. In order to eliminate these errors, three types of procedure have been adopted by experimenters :—

1. To repeat an experiment for a long sequence of years, so that the average yield may be taken to indicate the

result not of a single year's weather, but of the prevailing climate of the district.

2. To repeat the same experiment on a large number of farms, so that the average yield may indicate not the result of a single soil, but the average result of the soils of the region explored.
3. To repeat the same experiments on small plots on an apparently uniform piece of land, and so to obtain some estimate of the experimental errors of field experimentation.

The difficulties encountered by the first method are great expense, delay in arriving at definite conclusions, cumulative effect of soil heterogeneity and uncertainty to what extent the discrepancies between different years are ascribable to weather differences and to what extent to experimental errors.

The difficulties of the second method are expense in the absence of widespread and intelligent support from the farmers, unrepresentative character of the weather of a single season and uncertainty to what extent discrepancies between different farms are ascribable to soil differences, to experimental errors or to weather differences.

The third method possesses the advantage of attempting not merely to " average out," but to evaluate the causes of variation; by itself it makes no attempt to study the variations due to soil and weather, but deliberately aims at evaluating the experimental errors and so of obtaining a result of known accuracy. The principal difficulty encountered has been the marked heterogeneity often found on apparently uniform pieces of land. The soil heterogeneity has often not merely detracted from the accuracy of the results, but has vitiated the estimates of error in such a way that the degree of accuracy of the results is in reality unknown.

These difficulties of the method of experimentation may be overcome by the replication of small plots. A valid estimate of accuracy may be achieved by arranging the plots in the field so that they conform to the requirements of the statistical theory used in the reduction of the data. To this end, definite rules may now be laid down. The lowering of the experimental error may be achieved to a greater extent than has hitherto been attempted by the systematic adoption of the principle of local control, by which plots to be compared are set out on land of comparatively similar quality, without vitiating the estimate of the experimental error calculated from the totality of the results.

Testing these new principles of procedure upon the results of uniformity trials, such as that of Mercer and Hall (1910), it appears that when small plots (1/200th acre) are practicable, the comparative values of, say, five different treatments or varieties may be obtained from an acre of land with errors within 1 per cent., and moreover with known accuracy. The actual arrangement may be varied to meet other requirements, but for small plot work with four, five or six treatments to be

compared, the Latin Square, replicated and randomised, apparently always gives highly accurate results.

The bearing of this advance on plot experimentation in all its branches is obvious. If plot experiments of known accuracy are repeated either upon different soils or under different weather conditions it becomes possible to distinguish discrepancies due to experimental errors from those due to changed conditions. Where the latter are of importance, it is possible to evaluate them analytically, and the results afford valuable guidance in showing in what soils and in what regions a proposed change in variety, in manurial treatment or in tillage procedure is likely to be beneficial or the reverse. In all cases the need for the very numerous results in order to average out uncontrolled causes of error can be obviated by the use of fewer observations of known accuracy under known conditions.

APICULTURAL INVESTIGATIONS.

Work has been directed towards the solution of two practical problems of importance to beekeepers and is being carried out by Mr. D. M. T. Morland.

(*a*) The suitability of metal " semicomb " in place of wax foundation as a basis for comb building.

The results so far obtained appear to indicate that the metal combs are not suitable for brood rearing in the climate of this country. The Queens did not lay well in them, the brood was scattered and the population consequently not kept up. Moreover, the larvæ tend to leave the metallic cell base and to work upwards towards the wax extension at the mouth of the cell.

Temperature appears to be maintained only at the expense of the consumption of an undue quantity of stores. It is probable that more adequate protection than that afforded by the simple air space of the W.B.C. type of hive is needed when using these combs. It is intended to test this point in the future.

It was also noted that the bees were quick to detect small inaccuracies in manufacture of the artificial cells, and where the cells were on the small side the bees endeavoured to correct matters by missing out a row every now and then and faulty combs were the result.

It was found that a strong stock would store honey in metal combs in the supers. The season of 1924 was, however, such a poor one in this locality that the test cannot be considered as fair.

(*b*) The situation of the frames in relation to the hive front.

The data respecting the situation of the frames in relation to the hive front need to be analysed more fully than at present before reliable conclusions can be drawn. The work has, however, brought to light useful indications for future enquiry.

The chief method in both these investigations has been a consideration of temperature conditions within the hive. It is intended to continue work on these lines and also to make a preliminary study of moisture and carbon dioxide in the hives.

In the summer of 1924 a number of beekeepers representing various county beekeepers' associations met and had a discussion

at the Experimental Apiary. During the period under review Mr. Morland has given six lectures and demonstrations before gatherings of beekeepers in various parts of the country.

THE ASSOCIATED FARMS.

Woburn.

In 1921 the Royal Agricultural Society gave up the Woburn Experimental Farm which they had carried on continuously since 1870, and its two best known fields—Stackyard and Lansome—were in October, 1921, taken over by the Rothamsted Experimental Station so as to ensure the continuance of the permanent wheat and barley experiments which are second only to those of Broadbalk and Hoos fields in point of age. The necessary funds are obtained from a special grant of the Ministry of Agriculture. Dr. Voelcker continues to supervise the experiments as he has done since 1890; the continuity of the records is therefore assured. It should be recorded that he acts in an honorary capacity, freely giving much time and trouble to this work. His report will be found on p. 77.

Leadon Court.

In December, 1922, E. D. Simon, Esq., then Lord Mayor of Manchester, offered us the use of his farm at Leadon Court, Ledbury, for experimental purposes, himself generously defraying the expenses incurred. It was decided to devote the whole farm to a test of the soiling system of keeping dairy cows, which has aroused much interest among farmers. Small scale trials at the Harper Adams Agricultural College had indicated the feasibility of all the processes involved, but no conclusions as to the economic value of the system could be reached. Mr. J. C. Brown was appointed manager and retained the post till February, 1925, when he was succeeded by Mr. J. H. Hellier.

The farm is 240 acres in extent, there being at present 86 acres of arable and 144 of grass, of which 20 acres will be ploughed out, making altogether 106 acres of arable and 124 of grass: in addition there are 10 acres of wood and waste.

During 1923 and 1924 it maintained a herd of 100 dairy cows and, in addition, some of the young stock and a certain number of pigs. The stocking, however, has proved to be too heavy and some reduction is now being made.

The cropping scheme of the arable land has been as follows:—

	Oct., 1922–Sept., 1923.	Oct., 1923–Sept., 1924.	Oct., 1924–5.
	Acres.	Acres.	Acres.
Mangolds	8	8	8
Marrow stem kale	17	20	16
Mixtures (wheat and peas; rye, beans and peas; beans, peas, wheat, barley	19	35	55
Turnips		9	
Clover, etc.		5	
Wheat	42	9	7
Total	86	86	86

Of the mixtures part is fed green, part is converted into hay, and part is allowed to ripen, yielding grain and fodder straw. The disadvantage of the cropping of 1924 was that it yielded insufficient straw for fodder and bedding.

The financial returns have been disappointing but it is believed that the initial difficulties are now overcome.

DEMONSTRATIONS AND LECTURES TO FARMERS AND STUDENTS.

The appointment of Mr. H. V. Garner as Guide Demonstrator has made it possible for the Station widely to extend facilities for visiting the plots. Farmers, agricultural students and agricultural workers are cordially invited to Rothamsted at any time convenient to themselves. May and June are good months for seeing the grass plots, July for the cereals, and September and October for the mangolds and potatoes. In the Winter, Mr. Garner is available for giving lectures on the Rothamsted results to Farmers' and Farm Workers' Clubs and similar organisations.

SCIENTIFIC PAPERS

Published 1923 and 1924.

CROPS AND PLANT GROWTH: STATISTICAL METHODS AND RESULTS.

(Botanical, Chemical and Statistical Departments.)

(a) Crops and Plant Growth.

I. Winifred E. Brenchley. *"The Effect of Iodine on Soils and Plants."* Annals of Applied Biology, 1924, Vol. XI., pp. 86-111.

Attempts to find an economic use for iodine in agriculture either for partial sterilisation or as a direct means of increasing growth led in the main to negative conclusions. There was no definite evidence of partial sterilisation, nor of any reduction in loss from "damping off" of tomato seedlings as a result of treating the soil with iodine dissolved in sodium iodide solution.

Strong doses of iodine inhibited or badly checked germination of mustard. Some of the plants made a striking recovery and ultimately surpassed the untreated controls in green and dry weight. If some time elapses between treatment and sowing the mustard is unaffected, showing neither the initial toxic effect nor the later recovery and stimulation.

Barley is more easily injured than mustard by iodine.

II. Amar Nath Puri. *"Effect of Methyl and Ethyl Alcohol on the Growth of Barley Plants."* Annals of Botany, 1924. Vol. XXXVIII., pp. 745-752.

Experiments were carried out in water culture to determine the effect of various alcohols on barley when applied to the roots. Ethyl alcohol proved to be more toxic than methyl alcohol, the difference in the toxicity being not merely one of degree, but of kind. Ethyl alcohol favours the growth of ear shoots and the suppression of vegetative leaves, while methyl alcohol favours the growth of leaves and not that of the ear shoots. In the later stages of growth plants are able to withstand the toxic action of ethyl alcohol much better than earlier in life.

III. W. E. Brenchley and H. G. Thornton. *"The Relation between the Development, Structure and Functioning of the Nodules on* 'Vicia faba' *as influenced by the Presence or Absence of Boron in the Nutrient Medium."* Proceedings of the Royal Society. B. 1925.

The work deals with the growth and functioning of nodules on *Vicia faba*, comparing those grown in culture media from which boron has been excluded with those supplied with boron.

In the absence of boron the vascular supply of the nodule is defective. The strands are entirely absent, or weakly developed, running only a short distance into the nodule. The nodules having no vascular strands remain minute and are usually buried

in the cortical tissues, and the bacteria do not swell out to form the so-called "bacteroids." In plants grown without boron, the number of nodules that attain macroscopic size is much reduced. When weakly developed strands enter the nodule, the amount of tissue containing bacteroids is closely correlated with the extent of the strands.

In the plants bearing these abnormal nodules the quantity of nitrogen fixed per nodule is small, being, in one experiment, less than one-tenth of that fixed in normal plants. The defective vascular supply is thus accompanied, on the one hand, by a reduced development of "bacteroid" forms and, on the other hand, by reduced nitrogen fixation.

In the absence or weak development of vascular strands in the nodule, the bacteria tend to become parasitic, attacking the protoplasm of the host cell. This attack is chiefly directed towards the more densely protoplasmic cells of the nodule. It is suggested that this change in the relations between the micro-organism and its host is connected with the loss or reduced supply of the carbohydrate energy material normally brought into the nodule by the vascular strands, the bacteria thus being reduced to making use of the protoplasm of the host as a source of energy.

IV. E. J. Russell. Journal of the Institute of Brewing. A full account of the work discussed on p. 17 of this report.

V. H. Lloyd Hind. "*Report on the Analyses of the Barleys of* 1922 *and of the Malts made from them.*" Journal of the Institute of Brewing, 1924. Vol. XXX., pp. 969-986.

This report gives the results of the analyses of the barleys grown under the auspices of the Institute of Brewing Barley Research Scheme in 1922, together with those of the malts made from them.

The first season's determinations were necessarily of an exploratory character, quality being a very elusive property which has not yet been reduced to exact chemical terms. The relationships between the total nitrogen and the other quantities generally estimated in malt analyses have been studied. The usual physical valuation of barley, good as it often is in the hands of experts, is shown to fail in certain conditions, some of the low valued barleys giving quite useful malts. The influence of regional conditions, soil, season, etc., on the composition of the barley and malts is shown to be greater than that of the different manurial treatments at each centre.

(*b*) Statistical Methods and Results.

AGREEMENT OF THEORY AND OBSERVATION.

VI. R. A. Fisher. "*Statistical Tests of Agreement between Observation and Hypothesis.*" Economica, 1923. Vol. III., No. 8, pp. 139-147.

In all quantitative work, both in biology and in agriculture, tests of agreement between observation and hypothesis assume

a critical importance. Unfortunately, as early as 1900, a mathematical error was introduced into the statistical theory of goodness of fit, which has led to many inconsistencies. This error, in its application to contingency tables, was pointed out by Fisher (1922), and the method of correction was at the same time indicated. In the present paper the disputed case of the fourfold table is treated in detail. A mathematical proof of the corrected formula is given, and the experiments of Yule, designed to test this specific point, are shown to agree well with the corrected formula, while they are wholly inconsistent with the formula previously in use.

ERRORS OF OBSERVATION.

VII. R. A. FISHER. "*Note on Dr. Burnside's recent Paper on Errors of Observation.*" Proceedings of the Cambridge Philosophical Society, 1923. Vol. XXI., pp. 655-658.

In small sample work, such as prevails in agricultural experimentation, the traditional methods standardised in biometry and in the theory of errors break down, so that more precise methods must be used. The first of these was developed by "Student" in 1908. In 1923 Burnside independently arrived at formulæ similar to, but not identical with, those of "Student." In the present note attention is drawn to "Student's" paper, and an exact proof is given of the accuracy of his formulæ.

THE PARTIAL CORRELATION COEFFICIENT.

VIII. R. A. FISHER. "*The Distribution of the Partial Correlation Coefficient.*" Metron., 1924. Vol. III., pp. 329-332.

In 1915 Fisher gave the exact sampling distribution of the correlation coefficient, and showed that the current formula for its probable error was inadequate when applied to small samples. In the present paper it is shown that the same formula, with a simple modification, is applicable to the distribution of the partial correlation coefficient. The theoretical result so obtained is shown to be in agreement with the experimental data hitherto available.

STATISTICAL REQUIREMENTS OF ACCURATE TESTS.

IX. R. A. FISHER. "*The Conditions under which χ^2 measures the Discrepancy between Observation and Hypothesis.*" Journal of the Royal Statistical Society, 1924. Vol. LXXXVII., pp. 442-450.

In making tests of goodness of fit the expectations have often, or indeed usually, to be reconstructed from the actual data with which they are to be compared. In such cases it had not been observed that it is necessary that the methods used in this reconstruction should not involve errors of fitting comparable to the errors of random sampling. In the present paper it is demonstrated that this requirement can only be fulfilled if the statistics used in the reconstruction, are not only consistent, but efficient statistics. When all statistics so employed satisfy the criterion of efficiency, it is demonstrated that the measure of discrepancy, χ^2, may, in large samples, be used with precision.

YIELD OF BARLEY.

X. W. A. MACKENZIE. "*Studies in Crop Variation. III. An Examination of the Yield of Dressed Grain from Hoos Field.*" Journal of Agricultural Science, 1924. Vol. XIV., pp. 434-460.

Records of the barley yields for 70 years have been analysed in the same manner as in the earlier study of the Broadbalk wheat results. Thirteen of the plots supply an unbroken record of manurial treatment. The variation of these is analysed into three portions representing (I) annual variations ascribable to variations in the weather; (II) steady deterioration ascribable to soil exhaustion; (III) slow changes other than steady deterioration. The annual variations are in general similar in comparable plots to those found with wheat, barley being on the whole the more variable. The average yields bring out the striking fact that no gain in yield can be ascribed to dressings of sulphate of potash, although the responses to superphosphate, rape cake and silicates (in the absence of superphosphate) are in all cases excellent. The failure of potash to improve the yield is brought out decisively by a comparison of the rates of deterioration, which seem to indicate that plots receiving potash have fallen off more rapidly than parallel plots without potash. The slow changes other than steady deterioration are smaller than on Broadbalk, and do not indicate, as on that field, any single simple explanation.

EFFECT OF MANURES ON GOUT FLY ATTACK.

XI. " MATHETES." "*Statistical Study of the Effect of Manuring on Infestation of Barley by Gout Fly.*" Annals of Applied Biology, 1924. Vol. XI., pp. 220-235.

This paper is a statistical analysis of the extensive data on gout fly infestation compiled by the Entomological Department for the years 1922 and 1923. (*See* Paper XLIX.) A preliminary examination of the agreement of parallel samples showed that in the data from Woburn and from the several experiments with malting barley the infestation was homogeneous over each plot. In two of the malting barley series significant differences appeared in the infestation of different plots; the same effect was even more strongly shown at Woburn. On Hoos field (1922) the individual plots were not homogeneous in infestation, but the differences between plots were so large and so consistently related to manurial treatment as to deserve a more detailed investigation.

Of ten comparisons possible with superphosphate all indicated that this manure materially decreases gout fly infestation, even in the two cases where, in the absence of nitrogenous manuring, it has little effect upon the yield. The percentage infested, which in the absence of this manure ranged from 20 to 11, is reduced on the average by 5.1; similarly, rape cake reduced the percentage by 4.2; potassium, sodium and magnesium salts by 3.8;

nitrate of soda by 3.4; and ammonium salts by 2.1. Silicates, although in the absence of phosphate they materially increase the yield, have no apparent effect upon gout fly infestation.

The data for 1923 were more satisfactory in that the plots this year were homogeneous. The differences in infestation associated with manurial treatment were on the whole similar to those of 1922. Phosphates, potassium, sodium and magnesium salts and rape cake again reduced infestation materially; silicates were again inoperative, but the small reduction in infestation ascribable in 1922 to nitrogenous mineral manures was absent.

RAINFALL AND WHEAT YIELDS.

XII. R. A. Fisher. *"The Influence of Rainfall on the Yield of Wheat at Rothamsted."* Philosophical Transactions of the Royal Society of London, B., 1924. Vol. 213, pp. 89-142.

This paper is the report of the methods and results of a large scale statistical reduction of the Rothamsted records of rainfall and wheat yields. The objects of the enquiry were (I) to ascertain the actual effects of varying rainfall as a factor in crop variation; (II) to discover the differential responses to rainfall of crops grown under different manurial treatments; (III) to lay a foundation both of statistical method and of ascertained fact for the agricultural evaluation of a particular season's weather, as is required for any effective system of agricultural insurance.

The greater part of the paper is devoted to the solution of mathematical problems, and the development of statistical methods, adequate to handle the type of data which it is required to treat. The procedure which emerges from the solution of these problems consists in making a detailed analysis of the weather sequence in each individual year for which crop records are available, so as to obtain measures of the several meteorological characteristics of each year. The yields are then expressed in terms of these measures in such a way that the average effect of a given weather variation upon the final crop can be calculated for all times of the year.

This procedure is applied to 65 rainfall sequences, and the average effect at all times of the year of an inch of rainfall is obtained for the 13 plots of Broadbalk wheat field which have been for the whole period under uniform treatment. Plots differently manured show very striking differences in the rainfall response, indicating that the prevailing climate is a considerable factor in determining the suitability of manurial dressings. All plots show that the rainfall of the district is on the average in excess of the requirements of wheat, but several plots indicate that more rain would be advantageous in October. All plots receiving nitrogenous fertilisers, including the 17 and 18 mineral series which receives only residual nitrogen, show a considerable loss of yield due to rain in January, which is apparently due to the loss of nitrates in drainage water. Those plots in which nitrogen deficiency is of rarest occurrence, such as the dunged

plot and plots 10 and 11, show an even heavier loss due to rainfall in July and August.

Rainfall variations make an important contribution to the yield variation observed. In this respect rain is perhaps more important than any other single meteorological factor. It will not be possible to treat the other meteorological factors with the same precision, since the records of temperature and sunshine do not go back to the beginning of the experiments.

See also paper No. XVII.

II. METEOROLOGY.

(Physical and Statistical Departments.)

XIII. W. B. HAINES. "*A Comparison of the Radiation Recorders at Rothamsted.* Journal of the Royal Meteorological Society, 1925. Vol. LI., pp. 95-100.

This paper deals with a comparison of the readings taken at Rothamsted with three types of radiation recorder. The first is a recorder of the Callendar pattern, depending upon the difference in temperature between a black and a bright resistance exposed to the sky. These readings are taken as standard. The second instrument (the Wilson Radio-integrator) reads the amount of alcohol which distils from a bulb exposed to the radiation into a similar shielded bulb. The third set of data is the record of hours of bright sunshine from the widely used Campbell-Stokes apparatus. Reference is also made to a fourth set of data, that given by an evaporimeter of the porous candle type, since the readings of this instrument are correlated to the amount of radiation.

The alcohol integrator gives readings much too low during the winter months. The readings can be fitted with fair accuracy by a formula of simple parabolic type. The possibility of introducing a temperature correction is discussed.

The hours of bright sunshine should be corrected by a factor depending upon the time of day and year (*i.e.*, upon the sun's altitude). A formula deduced by Ångstrom from the Stockholm data, for calculating total radiation from hours of bright sunshine, is examined and found fairly satisfactory for the Rothamsted data. It is concluded that such a formula, based upon the data at one station, could with due caution be adopted for another station.

The evaporimeter results follow the hours of sunshine very closely, but some care is needed in the choice of a site for this instrument.

XIV. W. D. CHRISTMAS. "*Notes on the Weather at Rothamsted.*" "Nature," Oct. 27th, 1921; Jan. 16th, 1922. "The Times," Jan. 26th, July 4th, Aug. 2nd, Sept. 3rd, Oct. 1st, Nov. 2nd, Dec. 2nd, 1923; Jan. 2nd, Mar. 1st, June 2nd, Sept. 1st, 1924; Jan. 1st, 1925.

III. THE SOIL.

(Chemical and Physical Departments.)

(*a*) MECHANICAL ANALYSIS.

XV. B. A. KEEN AND W. B. HAINES. *"On the Effect of Wear on Small Mesh Wire Sieves."* Journal of Agricultural Science, 1923. Vol. XIII., pp. 467-482.

Fine mesh wire sieves play an important part in agricultural science, especially in specifications for certain artificial fertilisers, and in mechanical analysis of soil.

The uniformity of new and worn sieves was measured with respect to the linear dimensions and area of the holes, and the diameter of the wire.

Unused sieves woven to the specification of the Institute of Mining and Metallurgy compared well, on the whole, with the specification, but in used sieves the variations were much greater: in one instance, 70 per cent. of the apertures were 25 per cent. in excess of standard area, and no less than 36 per cent. were 50 per cent. over standard. In some of the sieves the frequency distribution curves of the data showed double peaks, and the actual observation showed that there was a systematic distribution of values corresponding to these two peaks. It would appear that the guides in one of the combs through which the warp wires are led during weaving had become displaced sideways, thus giving alternate strands of wide and narrow holes.

A calculation of the increase of area of the apertures due to stretch of the sieve in use led to values below those actually observed. This discrepancy is due to the wires becoming displaced from their original positions under the rubbing action employed in mechanical analysis.

Of the two systems of weaving—double and single—the former is stronger, but the latter is more uniform, since the warp and weft grip one another more tightly and more often in a given area. The fact that it is intrinsically neither as strong nor as durable as a double weave is an advantage, as with ordinary use, some of the strands break and the sieve is discarded before any very serious alteration in aperture area has arisen.

XVI. J. R. H. COUTTS, E. M. CROWTHER, B. A. KEEN, AND S. ODEN. *"An Automatic and Continuous Recording Balance. (The Odén-Keen Balance.)"* Proceedings of the Royal Society. A., 1924. Vol. CVI., pp. 33-51.

In connection with (*a*) the newer methods of mechanical analysis which involve only a single sedimentation, and (*b*) further experiments on the evaporation of water from soil, there arose an urgent necessity for some form of automatic self-recording balance. At the request of Prof. Sven Odén, of Stockholm, the Soil Physics Department has devised an improved form of his original type of recording balance. The control is effected electromagnetically. The current passing through a solenoid is automatically adjusted, so that the force of attraction on a magnet

suspended from one pan of an analytical balance is just sufficient to keep the balance in equilibrium. The adjustment of this current is effected by the movement of a sliding contact along slide wires, and this movement is in its turn controlled by the slight swing of the pointer attached to the balance beam, as the latter moves from its equilibrium position. When the current —and hence the weight on the second pan of the balance— reaches a pre-arranged value, a subsidiary circuit is automatically closed, and a small phosphor-bronze ball of known weight is deposited on the pan above the magnet, the sliding contact is drawn back to its initial position, and the cycle of operations recommences.

The arrangement of the circuits is such that the distance of the sliding contact from its zero position is to a close approximation linearly related to the current, and hence a recording-ammeter is not needed, as a record on a rotating drum of the slider position is sufficient to give the required data. The records consist of a series of stepped curves and a very open scale is obtained.

The apparatus can be used with no loss of sensitivity up to the maximum load the balance is designed to carry. Further, the sensitivity can be very simply adjusted, so that both rapid and slow changes of weight can be recorded.

The apparatus can be employed with advantage in experiments involving a continuous measurement of increasing or decreasing weight, and its application to the study of sedimentation and flocculation of soil particles, and the evaporation of water from fibres is illustrated in the present paper.

The earlier work was carried out with the assistance of the Cambridge Instrument Company, 45, Grosvenor Place, London, and the completed form of the instrument has been placed by them on the market.

XVI. (*a*). B. A. Keen. "*The Odén-Keen Automatic Balance.*" Proceedings of the Fourth International Conference on Soil Science. Int. Inst. of Agric., Rome, 1924.

(See preceding paper for abstract.)

XVII. R. A. Fisher and Sven Oden. "*The Theory of the Mechanical Analysis of Sediments by Means of the Automatic Balance.*" Proceedings of the Royal Society of Edinburgh, 1924. Vol. XLIV., pp. 98-115.

Ideally the mechanical analysis of a soil should enable us to state what fraction of the soil consists of particles smaller than any assigned size. In 1916 Odén showed that the distribution by size of the particles could be obtained by a sedimentation process. The necessary sedimentation curve may most readily be obtained by means of the Odén-Keen automatic balance. (*See* paper XVI.) The present paper consists of :—

(*i*) A simplified mathematical statement of the theory of the changes taking place in the fluid during sedimentation, showing

from what physical observations the required distribution curve may be derived, and verifying Odén's formula.

(*ii*) A criticism of Schloesing's sedimentation formula.

(*iii*) The development of practical methods for the statistical treatment of the readings of the automatic balance in order to derive the required curve of size distribution.

(*iv*) An examination of the degree of accuracy obtained in a duplicate experiment carried out on Rothamsted soil, by the Physical Department; and of the incidence of random and systematic errors in this experiment.

(*v*) A discussion of the causes of error in the current technique, and of the means of control of the fluid motions to which they appear to be due.

(*b*) PHYSICAL PROPERTIES OF SOIL.

XVIII. B. A. KEEN. "*Recent Advances in Soil Physics.*" Proceedings of the Fourth International Conference on Soil Science. (Int. Inst. of Agric., Rome, 1924.)

A review of work in this subject since 1900, and a critical discussion of some outstanding problems.

XIX. E. M. CROWTHER and J. R. H. COUTTS. "*A Discontinuity in the Dehydration of Certain Salt Hydrates.*" Proceedings of the Royal Society. A., 1924. Vol. CVI., pp. 215-222.

During a preliminary study of the evaporation of water from soils and colloidal material, experiments were made with the simplest solid systems, viz., crystalline hydrates, using the automatic balance (paper XVI). In the evaporation of water from $CuSO_4.5H_2O$ and $BaCl_2.2H_2O$ at 100°C, a marked discontinuity was noticed. The evaporation proceeded rapidly up to the formation of the definite hydrates $CuSO_4.3H_2O$ and $BaCl_2.1H_2O$, but was almost completely interrupted at these points. After varying periods the evaporation recommenced and proceeded rapidly to the formation of $CuSO_4.1H_2O$ and $BaCl_2$. A tentative explanation is advanced, based on Langmuir's treatment of actions at surfaces.

XX. B. A. KEEN. "*On the Moisture Relationships in an Ideal Soil.*" Journal of Agricultural Science, 1924. Vol. XIV., pp. 170-177.

This paper consists of a critical examination of a portion of Wilsdon's theoretical investigation on moisture relationships. Wilsdon's investigations appeared to show that the maximum moisture holding capacity of an ideal soil (*i.e.,* one built up of uniformly packed solid spheres all having the same radius) was 23.46 per cent. Further, his experimental and theoretical work indicated that the total amounts of water held by the soil colloids, as distinct from the " free " or interstitial water was 4.7 x (Hygroscopic Coefficient). The total moisture holding capacity of an ordinary soil would therefore be :—4.7 x (Hygroscopic Coefficient) + 23.46, which is remarkably close to Briggs' well

known empirical expression :—4.3 x (Hygroscopic Coefficient) + 21. The present paper shows that the derivation of the value 23.46 per cent. cannot be substantiated, because the analyses take no account of the fact that the adjacent water wedges surrounding each point of contact of the spheres come into contact with each other at a moisture content very considerably below 23.46 per cent. The value is in fact much too high, and Briggs' figure 21 still remains empirical. An explanation is suggested for the gradual decrease with height in the moisture content of a long unbroken soil column saturated at the base.

XXI. E. M. Crowther and A. N. Puri. *"The Indirect Measurement of the Aqueous Vapour-pressure of Capillary Systems by the Freezing-point Depression of Benzene."* Proceedings of the Royal Society. A., 1924. Vol. CVI., pp. 232-242.

With a view to developing a technique for the measurement of vapour pressures in relatively dry soil, a study was made of the freezing-point depressions (F.P.D.) of moist benzene in equilibrium with the soil. Sidgwick's assumed proportionality between the F.P.D. of benzene and the aqueous vapour pressure of the with the soil. Sidgwick's assumed proportionality between the F.P.D. of benzene and the aqueous vapour pressure of the material with which it is in equilibrium, was substantiated by experiments on sulphuric acid-water mixtures. All soils showed a systematic deviation, the observed F.P.D. being in all cases greater than that calculated from the vapour pressure. By postulating a system of micropores or capillaries in the soil, and allowing for the effect of benzene on the surface tension of the soil water, an expression was obtained which agreed with the observed values. This agreement supports the view that many of the observed colloidal properties of soils can be interpreted in terms of minute capillaries.

XXII. A. N. Puri, E. M. Crowther and B. A. Keen. *"The Relation between the Vapour Pressure and Water Content of Soils."* Journal of Agricultural Science, 1925. Vol. XV., pp. 68-88.

Much of the modern work on the physical properties of soils has been interpreted on a colloidal basis. There is evidence that the colloidal portion can be regarded as possessing a reticulate structure, possibly analogous to that shown to exist in silica gels. These minute pores largely control the vapour pressure of soils at different moisture contents, and a measurement of this property offers a promising line of attack on the physical relations between the colloidal soil material and water.

Three experimental methods were tried and the most convenient was one in which the soils were allowed to come into equilibrium in a vacuum dessicator, over sulphuric acid of the desired strength. Some of the soils were subjected to various treatments known to affect other physical properties, such as successive wetting and drying, heating, and addition of salts. The general results were as follows :—The water absorption at

definite relative humidities is almost independent of temperature over the range 20° to 40° for high relative humidities, but decreases markedly with increasing temperatures for the lower relative humidities. This influence of temperature on the relative vapour pressures of moist soils is connected with the fact that dry soils liberate heat when wetted. All soils show considerable hysteresis in their vapour pressure relationships. The apparent water content or loss on heating of a soil increases regularly with the temperature of heating up to about 200°C. Soils heated to various temperatures between 100° and 200° C. show substantially the same water absorptions at different relative humidities. The water absorption by a soil is markedly affected by previous treatment with agents known to disintegrate the soil.

The vapour pressure curves of the various soil fractions, including clay, differ only slightly in type from that of the soil, although the absolute amounts of water taken up increase with the increasing specific surfaces.

Some preliminary data are given to show the complicated effects resulting from addition of salts to the soil.

XXIII. A. N. Puri and B. A. Keen. "*The Dispersion of Soil in Water under Various Conditions.*" Journal of Agricultural Science, 1925. Vol. XV., pp. 147-161.

A study has been made of the intensity of the forces binding soil particles together, when the soil has been previously subjected to treatments simulating various field conditions, and certain laboratory processes connected with physical, chemical and biological investigations.

The technique consisted in shaking soil with water under reproducible conditions, allowing the mixture to stand for 24 hours, and then determining the concentration of soil in the top 8.5 cms. of the suspension : this was expressed as a percentage of the original concentration, and the value thus obtained was called the dispersion factor of the soil under the conditions of treatment.

The following conclusions emerge from the data :—

(*a*) Disintegration of soil aggregates by shaking in water proceeds continuously, rapidly at first and then more slowly. After nearly 100 hours of shaking, the dispersion factor is still slowly increasing, and its change with time after completion of the first rapid increase can be expressed by the equation :—

$$d = a + K \log t.$$

where d = disperson factor, t = time of shaking, a and K = constants

(*b*) The dispersion factor depends on the original concentration of the soil. There are slight but systematic changes in the lower concentrations and flocculation occurs when a certain maximum concentration is passed. It is probable that, besides the increase in concentration, the concomitant increase in the amount of soluble salts present is concerned in the flocculation process.

(*c*) The dispersion factor for clay decreases continuously with decrease in initial moisture content, whereas with soil a stationary value is reached when the moisture content is reduced to a certain

value. Contact with water or water vapour breaks up soil aggregates only very slowly.

(*d*) A progressive decrease in the dispersion factor is caused by heating the soil to temperatures over 110° C., but up to this temperature no reduction appears. In the case of clay, heating to 100° C. greatly reduces the dispersion factor.

(*e*) The influence of electrolytes is progressive and gradual, and not a sharp flocculation or deflocculation. With successive increases in concentration of good deflocculants the dispersion factor increases to a maximum, then decreases slowly, and then rapidly until complete flocculation occurs.

(*f*) A comparison of various methods recommended for soil dispersion shows that the use of a rubber pestle is one of the most efficient means.

XXIV. A. N. PURI. "*A Critical Study of the Hygroscopic Coefficient of Soil.*" Journal of Agricultural Science, 1925. Vol. XV., pp. 272-283.

The Hygroscopic Coefficient, defined as the percentage by weight of water held by a soil when in equilibrium with an atmosphere saturated with water vapour, has been much used, especially in America, as a means of characterising a soil. Accurate determination of the value is not easy, owing, among other things, to the difficulty of maintaining a correctly saturated atmosphere. The present investigations were made with a technique deliberately refined beyond that possible in routine laboratory determinations, in order to obtain some idea as to the inherent value of the method itself, and of the justification of the conception of the Hygroscopic Coefficient.

The results, while incidentally clearing up the controversy whether the Hygroscopic Coefficient, as determined under ordinary conditions, increases or decreases with increase of temperature, show definitely that even with a very careful technique, only qualitative accuracy can be obtained. The paper concludes with a short discussion of the manner in which soil absorbs water vapour, in which the conception of the Hygroscopic Coefficient is criticised on physical grounds.

XXV. W. B. HAINES. "*Studies in the Physical Properties of Soils. I. Mechanical Properties Concerned in Cultivation.*" Journal of Agricultural Science, 1925. Vol. XV., pp. 178-200.

The general problem considered in this paper is that of supplying, by means of laboratory tests, data as to the mechanical behaviour of soils sufficient to form a basis for the mathematical treatment of ploughing and cultivation operations in the same way that other engineering problems are usually treated. As a first step to this end certain physical investigations already carried out at Rothamsted have been grouped together under the following heads :—

(*a*) Soil cohesion.
(*b*) Soil plasticity.
(*c*) Friction between a metal surface and soil.

In each case the variation of properties for different soil types is considered, as well as the variation in the same soil for different moisture contents.

(*a*) *Cohesion.* Atterberg's method was used, the apparatus being specially designed to give the cutting or breaking strain of prepared soil specimens. A comparison of the author's results with Atterberg's shows a difference in character of theoretical importance.

(*b*) *Plasticity.* A simple statement of the constants involved in measurements of plasticity is first made, in order to clear a certain confusion hitherto shown in applying the subject to soils. One of these constants, which may be called " the pressure of fluidity," was measured by a new method which has proved a sensitive means of classifying the behaviour of clays.

(*c*) *Surface Friction.* The apparatus used for friction measurements is described in another communication (*see* paper No. XXVI.). The results show very marked differences according to soil type, and throw an interesting light upon the theory of soil moisture relationships. The subject is a new one in soil measurements, and the method promises to be very effective in the physical examination of soils.

Although much remains to be done to fill in gaps in the data, the grouping together in this way has thrown into clearer relief many of the outstanding problems of soil physics.

(*c*) SOIL CULTIVATION.

XXVI. E. M. CROWTHER and W. B. HAINES. *"An Electrical Method for the Reduction of Draught in Ploughing."* Journal of Agricultural Science, 1924. Vol. XIV., pp. 221-231.

The frictional force between mouldboard and the soil constitutes an appreciable fraction of the total draught in ploughing. In this paper a simple electrical method is suggested and investigated for the reduction of friction on moist substances. In its application to ploughing, a current is passed through the soil having the mouldboard as the negative electrode. As moist soil exhibits the phenomenon of electro-endosmosis, and as the soil colloids have a negative charge, water moves through the moist soil towards the negative electrode under the action of the electric current. The mouldboard thus becomes covered with a water film, which should act as a lubricant and reduce the ploughing draught. Under laboratory conditions, striking reductions in friction were obtained. A number of field experiments showed that the device reduced the effort required in ploughing. The reduction was, however, much smaller than in the laboratory experiments, but there is considerable possibility of improvement in the method of applying the current, and thus obtaining greater reduction in draught. The method promises to have useful extensions to certain other cultivation processes such as mole drainage and deep ploughing. (*See* paper LXI.)

(*d*) SOIL REACTION.

XXVII. E. M. CROWTHER. "*Studies in Soil Reaction. III. The Determination of the Hydrogen Ion Concentration of Soil Suspensions by Means of the Hydrogen Electrode.*" Journal of Agricultural Science, 1925. Vol. XV., pp. 201-221.

An improved hydrogen electrode apparatus is described and its use illustrated by reference to a number of soils showing characteristic crop failures. The buffer action of soils is represented by titration curves giving the equilibrium pH values corresponding to additions of varied amounts of lime water. Adjacent or similar soils may show considerable differences in pH value with no change in their buffer action. In such cases any " lime requirement " method is likely to show results which are correlated with the pH values, but this cannot be the case in soils of different types with different degrees of buffer action. Additions of neutral salts cause considerable increases in the hydrogen ion concentrations of both acid and slightly alkaline soils. Sodium salts, including sodium hydroxide, always give lower hydrogen ion concentrations than the corresponding potassium or calcium salts. The titration curves of a soil in the presence of different amounts of a neutral salt run parallel; the buffer action of a soil is not affected by neutral salts. Extraction of a soil with water causes a considerable reduction in the hydrogen ion concentration, *i.e.*, an increase in pH value. This effect may operate in wet seasons in diminishing the infertility of acid soils and in increasing the stickiness of heavy soils. A number of soils showed a regular decrease of 0.1 in pH value for a two-fold increase in the soil-water ratio. This " dilution effect " and the " salt effect " appear to result from a complex equilibrium between the hydrogen ions and metallic cations, at the soil surface, and form important cases of " base exchange." The indicator methyl red gives erroneous results in turbid suspensions owing to the absorption by the soil of the red form, which is apparently a cation exhibiting " base exchange " with the soil.

XXVIII. E. M. CROWTHER. "*Studies in Soil Reaction. IV. The Soil Reaction of Continuously Manured Plots at Rothamsted and Woburn.*" Journal of Agricultural Science, 1925. Vol. XV., pp. 222-231.

The continuously manured grass plots at Rothamsted and barley plots at Woburn are acid, except in one or two cases. Sulphate of ammonia has caused a marked increase in acidity, and nitrate of soda a slight increase. The farmyard manure plot at Woburn is appreciably less acid than the unmanured. Mineral manures have had little or no effect on the reaction of the surface soil, but sulphate of potash has slightly increased the acidity of the subsoil below the more acid plots. There is some evidence that the acidity of the surface soil at Rothamsted is approximating to an upper limit of pH value 3.8, where large dressings of sulphate of ammonia are applied. The change in

pH value as a result of liming is less than that shown in the laboratory, owing in part to the reduction of the acidity of the subsoil. Application of amounts of lime equivalent to the Hutchinson-MacLennan " lime requirement " reduced the acidity by an amount equal to +0.5 to +0.7 in pH value, but the soils still remained appreciably acid.

XXIX. E. M. CROWTHER. *" Studies in Soil Reaction. V. The Depth-distribution of Reaction and Flocculation in Continuously Manured Soils."* Journal of Agricultural Science, 1925. Vol. XV., pp. 232-236.

The reactions of the unmanured and the limed and unlimed portions of the sulphate of ammonia plots on Rothamsted Park Grass and Woburn Barley plots change steadily with increasing depth, and at 36in. still show the same relations as in the surface soil. The difference in pH values between the limed and unlimed portions is substantially constant at all depths down to 36in. The reaction of the subsoil plays an important part in determining the effect of liming. The subsoils from the sulphate of ammonia plots at both centres are highly flocculated. Mixtures of 1 part of soil with 5 parts of water exhibit complete flocculation in the case of all samples below 9in. and the velocity of sedimentation decreases and the volume of the final sediment increases regularly and markedly with the depth. Such changes in soil texture possibly constitute an important factor in the effects due to a high surface acidity.

XXX. E. M. CROWTHER and W. S. MARTIN. *" Studies in Soil Reaction. VI. The Interaction of Acid Soils, Calcium Carbonate and Water, in Relation to the Determination of 'Lime Requirements.' "* Journal of Agricultural Science, 1925. Vol. XV., pp. 237-255.

The Hutchinson-MacLennan " lime requirement " method has given useful results in the hands of certain workers but not of all. The variations in " lime requirement " resulting from changes in the amounts of soil and calcium bicarbonate are shown to be connected with buffer action of the soil, as determined by electrometric measurements of the hydrogen ion concentration, after the addition of lime water. A systematic difference between the direct electrometric titration curves and the indirect titration curves calculated from the calcium bicarbonate experiments, is due to the variable calcium concentration of the bicarbonate solutions. In the presence of calcium chloride both methods show higher acidities for a given base absorption, and give almost identical titration curves. The Hutchinson-MacLennan " lime requirement " is always less than that equivalent to the amount of lime required to give a neutral solution (pH = 7.0) in the electrometric titrations, a result which accords with the field results quoted in the preceding papers. The calcium bicarbonate solutions after treatment with soil are quite acid, with pH values always less than 6.2, but the salt effect tends to give higher base absorption than is given for the same pH value in the titration Curves. Better values for the " lime requirement " are obtained by interpolating the results to a constant,

but arbitrary, calcium bicarbonate concentration. An empirical relationship has been found which enables such an interpolation to be made from a single experiment. The Hutchinson-MacLennan method can give no indication of the intensity of soil acidity, but it will serve a useful purpose in showing the amount of lime needed to reduce this acidity considerably; it gives guidance as to the amount of lime to apply, where pH measurements and other tests and observations have shown that lime is needed. The interaction of soil with calcium acetate and dicalcium phosphate give results of the same type as those given with calcium bicarbonate. Calcium carbonate suspensions, containing phenol red or cresol red, show an almost instantaneous colour change when poured on air-dry acid soil, owing to the decomposition of some calcium carbonate. The interaction of acid soil with calcium carbonate and water in full bottles liberates an amount of total acid, as carbonic acid and calcium bicarbonate, which is greater than that estimated by the Hutchinson-MacLennan method. Still greater quantities of acid are liberated when water is percolated through intimate mixtures of acid soil and calcium bicarbonate. These differences are to be explained by the higher pH values of the liquid at equilibrium, and the conditions approximate more closely to those obtaining in the field. (*See* paper LXII.)

See also Paper LVI.

XXXI. T. Eden. "*The Edaphic Factors Accompanying the Succession after Burning on Harpenden Common.*" Journal of Ecology, 1924. Vol. XII., pp. 267-286.

The floristic survey of Harpenden Common shows the succession of vegetation after the periodical fires to be *Rumex acetosella, Holcus lanatus, Agrostis.* Of the soil factors influenced by burning those of soil reaction (in terms of the Hutchinson-MacLennan Lime Requirement and pH measurement) and humus content show a gradation accompanying the progress of the succession. The nature of the acidity and its probable relation to the succession, the formation of humus and to burning are discussed.

(*e*) CHEMICAL PROPERTIES OF SOIL.

XXXII. H. J. Page and W. Williams. "*Studies on Base Exchange in Rothamsted Soils,*" Transctions of the Faraday Society, 1925. Vol. XX., pp. 573-585.

The content of exchangeable bases in the soil of certain plots on Broadbalk field, and the Grass Plots, Rothamsted, has been determined by Hissink's method. The results show that in the soil of Broadbalk field, containing excess of chalk :—

(*a*) The relative proportions of the different bases vary consistently with the manuring. In all the soils about 90 per cent. of the exchangeable bases (in equivalents) consists of calcium.

(*b*) The total content of exchangeable bases can be correlated with the amount of fine inorganic material (diameter of particles less than 0.005 mm.) and of organic matter.

(*c*) There is probably a gradual conversion of exchangeable potash to a non-exchangeable form, or *vice versa,* depending on whether potash manures are used or not.

In the acid soil of the Grass Plots, from which chalk is absent, the soils are all unsaturated, and the amount of exchangeable calcium can be correlated with the pH of the soil.

The bearing of these results on current theories of base exchange in soils, and on the relation between soil acidity and ionic exchange, is discussed.

XXXIII. N. N. Sen Gupta. "*Dephenolisation in Soil, Part II.*" Journal of Agricultural Science, 1925.

Soils possess the power of destroying phenol under conditions precluding the possibility of biological action. This power, which is greatly increased by preliminary acid-treatment of the soil, varies greatly from soil to soil. It is shown that this chemical dephenolising power of soils depends upon the presence of an oxidising agent, and that most of the action is due to the presence of manganese in the soil, probably in the form of manganese dioxide.

(*f*) CHEMICAL ANALYSIS.

XXXIV. T. Eden. "*A Note on the Colorimetric Estimation of Humic Matter in Mineral Soils.*" Journal of Agricultural Science, 1924. Vol. XIV., pp. 469-472.

An application to mineral soils of the method worked out for peat soils by Odén.

XXXV. H. J. Page. "*On the Perchlorate Method for the Estimation of Potassium in Soils, Fertilisers, etc.*" Journal of Agricultural Science, 1924. Vol. XIV., pp. 133-138.

The presence of chloric acid in the perchloric acid used for the estimation of potassium in soils, fertilisers and plant material by Davis's method gives rise to very erratic and erroneous results. Every sample of perchloric acid should, therefore, be tested for freedom from chloric acid before being used for the estimation of potassium.

In the application of Neubauer's method of treatment of the soil extract to a soil deficient in carbonates, it is sufficient to add only 0.1 gm. of calcium carbonate to the extract instead of the 0.5 gm. generally used. A considerable economy of perchloric acid is thereby effected.

XXXVI. E. M. Crowther and W. S. Martin. "*The Volumetric Determination of Total Carbonic Acid in Dilute Solutions of Calcium Bicarbonate.*" Journal of the Chemical Society, 1924. Vol. CXXV., pp. 1937-1939.

In the course of studies on soil reaction (papers XXVII-XXX), it was found that the standard method for the determination of total carbonic acid (excess barium hydroxide and

barium chloride titration) gives unsatisfactory results with solutions of calcium bicarbonate and tap waters, owing to the solubility of the precipitated calcium carbonate. If the precipitation is done in the presence of solid calcium carbonate in calcium hydroxide and calcium chloride, good results are obtained with short intervals of standing.

IV. THE SOIL ORGANISMS.

(Bacteriological, Mycological and Protozoological Departments.)

(*a*) BACTERIA.

XXXVII. H. G. THORNTON. "*On the Vibration Method of Obtaining a Suspension of the Bacteria in a Soil Sample, Developed by C. L. Whittles.*" Journal of Agricultural Science, 1923. Vol. XIII., pp. 352-353.

A criticism of the results obtained in preliminary work with this bacterial count method.

XXXVIII. H. G. THORNTON and N. N. GANGULEE. "*Seed Inoculation of Lucerne* (Medicago Sativa) *and its Relation to the Motility of the Nodule Organism in Soil.*" Nature, December, 1924.

Preliminary results of work on the passage of the nodule organism through soil and of the relation of this to seed inoculation. The addition of soluble phosphate to the milk suspension of bacteria used to inoculate seed was found, in pot experiments, to produce a large increase in nodule numbers.

XXXIX. P. H. H. GRAY and C. H. CHALMERS. "*On the Stimulating Action of Certain Organic Compounds on Cellulose Decomposition by Means of a New Aerobic Micro-organism that Attacks Both Cellulose and Agar.*" Annals of Applied Biology, 1924. Vol. XI., pp. 324-338.

A new micro-organism from soil is described that has the power of rapidly decomposing cellulose and agar. It can utilise either of these substances as the sole source of energy, and the ability to decompose these compounds is not lost after long subculturing in the laboratory. The organism has been named *Microspira agar-liquefaciens*. Pure-culture experiments showed that under conditions of adequate aeration this organism will decompose filter-paper to a greater extent when supplied with small quantities of xylose and lignin.

See also paper III.

(*b*) PROTOZOA.

XL. H. SANDON. "*Some Protozoa from the Soils and Mosses of Spitsbergen.*" Journal of the Linnean Society (Zool.), 1923. Vol XXXV., pp. 449-475.

The protozoa contained in 3 samples of mud, 8 samples of soil, and 14 samples of mosses from Spitsbergen have been investigated. An abundant fauna was found, most of which was identical with that occurring in the soils and mosses of temperate lands.

Seven new species of flagellates are described, of which, however, five have subsequently been found in soils from non-arctic regions.

XLI. H. Sandon and D. W. Cutler. *"Some Protozoa from the Soils Collected by the 'Quest' Expedition."* Journal of the Linnean Society (Zool.), 1924. Vol. XXXVI., pp. 1-12.

Soils were examined from St. Paul's Rocks, South Georgia, Elephant Island, Tristan da Cunha, Gough Island, St. Helena, St. Vincent, and San Miguel Azores. The protozoa found in the soils of these remote lands are mostly identical with those found in almost any ordinary English soil. It appears that there is a fairly well defined and characteristic soil protozoan fauna, which is practically ubiquitous. The richest fauna were those found in soils from Tristan da Cunha and Gough Islands, which had been manured with the dung of farm animals for many years. The poorest samples were from South Georgia and St. Vincent, which were all practically sub-soils.

XLII. D. W. Cutler. *"The Action of Protozoa on Bacteria when Inoculated into Sterile Soil."* Annals of Applied Biology, 1923. Vol. X., pp. 137-141.

Three portions of sterile soil were inoculated with bacteria alone, bacteria and amœbæ, bacteria and flagellates. The bacterial numbers were counted daily. The experiment showed that the bacterial population in soil free from protozoa is able to maintain a higher level for a longer period than when protozoa are present; and that the presence of protozoa is one of the factors concerned in keeping the numbers of bacteria below the level they might otherwise attain.

XLIII. R. V. Allison. *"The Density of Unicellular Organisms."* Annals of Applied Biology, 1924. Vol. XI., pp. 153-168.

The density of certain unicellular organisms of known diameter has been measured by Stokes' formula.

The average density of algal cells studied is 1.098 and that for the cysts of Gonostomum sp. 1.057.

The density of the algal cells was found to vary greatly between the larger and smaller sizes, while for intermediate cells it is fairly constant. The total variation in average density of protozoan cysts was much less marked.

During maturation, the cysts of a certain species of Colpoda decreased to one-fourth their original volume, while their average density increased from 1.04 to 1.06.

By the application of the formula of Hehner and Richmond to the density values so obtained, a tentative value has been derived for the actual dry matter of the cells studied. On this basis the dry matter of the young cysts (4 day) of Colpoda sp. amounts to 10.6 per cent. while at the later stage (20 day) it is 15.1 per cent.

XLIV. R. V. Allison. *"A Note on the Protozoan Fauna of the Soils of the United States."* Soil Science, 1924. Vol. XVIII., pp. 339-352.

The examination of a series of soil samples from widely divergent points in the United States shows a considerable uniformity in the distribution of the more important of the three protozoan sub-phyla, Flagellates, Ciliates and Rhizopoda. The range of type genera was found to be quite similar to that holding for English soils.

From quantitative studies upon these same samples it is suggested that a possible explanation of the divergent conclusions of English and American investigators may be found in the difference in the extent of the protozoan fauna in the respective materials investigated. Thus the biological phenomena which follow the partial sterilization of the soil and which have been so extensively studied by both groups of investigators, though admittedly similar in nature, may have as their fundamental basis groups of organisms of quite diverse natures.

XLV., XLVI. D. W. Cutler and L. M. Crump. *"The Rate of Reproduction in Artificial Cultures of* Colpidium Colpoda. *Parts II. and III."* Biochemical Journal. 1923-24. Vols. XVII., XVIII., pp. 878-886, 905-911.

The rate of reproduction of *Colpidium colpoda* has been tested in cultures derived from one or more animals isolated into small volumes of fluid. It is shown that in the main such cultures are comparable with mass cultures.

The allelocatalytic effect, described by Robertson, has been tested and found not to obtain with *Colpidium* when isolated into fluid whose volume varies from 0.5 to 8.5 mm. A few experiments are given in support of the contention that the rate of reproduction can be accelerated by the addition of small quantities of crushed bacteria or protozoa.

Experimental evidence is given that the number of divisions *Colpidium colpoda* undergoes in definite periods of time is intimately connected with the size of the bacterial population.

Further investigations on the relation between the size of the inoculum and the rate of reproduction demonstrates that the number of divisions steadily decreases as the number of animals inoculated increases.

(*c*) FUNGI.

XLVII. J. Henderson Smith. *"On the Early Growth Rate of the Individual Fungus Hypha."* The New Phytologist. 1924. Vol. XXIII., pp. 65-78.

The fungal hypha elongates at the tip only. The rate of elongation is at first very slow, but steadily increases as time passes, and eventually reaches a maximum value many times greater than the initial rate, and this is maintained for a long period. Different individual hyphæ show considerable differences in the actual rate and in the manner of development, but the majority behave similarly under similar circumstances. Although it increases as the length increases, the rate of extension is not

constantly proportional to the length of the hypha, but falls off continuously relatively to the length. The extension of branches follows the same process as that of the main hypha, and falls off in rate continuously relatively to the length; but as a rule a branch grows faster than its parent hypha, and in many cases the rate of extension of the total hyphal system (*i.e.*, parent hypha, branches, and sub-branches taken together) is constantly proportional for long periods to the total length. No evidence was found of any actual increase in the growth rate relatively to the amount of substance growing, such as is described in the case of bacteria, nor anything which suggests the formation during the hyphal development of any substance accelerating its growth.

See also "Fungus Pests and their Control, Wart Disease." Papers No. LVI., LVII.

V. THE PLANT IN DISEASE; CONTROL OF DISEASE.

(Entomological, Insecticides and Fungicides, and Mycological Departments.)

(*a*) INSECT PESTS AND THEIR CONTROL.

XLVIII. J. G. H. Frew. "*On the Larval Anatomy of the Gout-fly of Barley* (Chlorops tæniopus Meig.) and *two Related Acalyptrate Muscids, with Notes on their Winter Host-Plants.*" Proceedings of Zoological Society, London, 1923. No. LIV., pp. 783-821.

The metamorphosis of the Gout-fly is fully described with a detailed account of the external and internal anatomy of the mature larva. The structure of the larva in its first and second instars is also discussed. Included in this paper are observations on the metamorphosis of *Meromyza nigriventris* and *Balioptera combinata*—two little known minor pests of winter barley and wheat.

The extent to which all three species utilise wild grasses as winter-hosts has also been examined. *Chlorops tæniopus* has only been found in *Agropyrum repens* among the wild grasses examined. *Meromyza nigriventris* occurs in *A, repens, Festuca ovina,* and *Alopecurus pratensis; Balioptera combinata* occurs in *A, repens, Festuca elatior, Lolium perenne, Holcus lanatus,* and *Agrostis alba.* The following grasses have also been examined but do not appear to function as winter hosts for any species :—*Lolium. italicum, Poa pratensis, P. trivalis, P. annua, Agrostis vulgaris, Alopecurus agrestis, Arrhenatherum avenaceum, Anthoxanthum odoratum, Avena pubescens. Cynosurus cristatus,* and *Dactylis glomerata.*

XLIX. J. G. H. Frew. "*On* Chlorops tæniopus Meig." (*The Gout Fly of Barley.*) Annals of Applied Biology, 1924. Vol. XI., pp. 175-219.

Chlorops tæniopus passes through two generations per year. The winter generation is mainly upon couch grass but also occasionally upon winter wheat or upon self-sown wheat or

barley. The summer generation is mainly upon spring barley, but in seasons unfavourable to the fly couch grass may be utilised. Very rarely wheat is a summer host plant. The life-history is described in detail.

The type of distortion caused to the host plant depends on the stage of growth of the plant when attacked and the degree of distortion of the plants depends upon the rate of growth at the time of attack.

The relation of the fly to the different kinds of host plants is described, particularly as regards the winter generation, and is shown to vary with such factors as date of emergence of the flies, weather conditions during the oviposition period and amount of growth of the different kinds of host plants.

In dull and cool weather the flies will lay few eggs but are stimulated to rapid egg laying by bright and sunny weather. A single fly may lay about 150 eggs. More than one act of coitus is necessary to fertilise all the eggs which a female is capable of laying. The length of life of the imagines is probably about a fortnight for flies emerging in spring, but may be over two months for the autumn emerging flies.

Certain manures (particularly superphosphate) have a marked beneficial effect in reducing the infestation of summer barley by gout fly, owing entirely to their stimulating effect upon the maturing of the ear and the growth of the ear-bearing internode.

While small dressings of nitrogenous manures may reduce infestation, large dressings will not reduce it and may have a tendency to retard growth of the ear and so increase infestation.

Early sowing of spring barley is efficacious in preventing infestation by gout fly.

Preventative measures suggested are early sowing of spring barley, good cultural conditions on the soil, and manuring (*e.g.*, with superphosphate or farmyard manure) to stimulate early growth (*see* paper LXXII.).

L. J. Davidson. "*The Penetration of Plant Tissues and the Source of the Food Supply of Aphids.*" Report International Conference Phytopathology and Economic Entomology, Wageningen (Holland), 1923, pp. 72-74.

The food of aphids is the cell sap of plants, which they obtain by penetrating the tissues by means of their piercing, suctorial mouth-parts. The mechanism of piercing and suction and the action of the insects' saliva on the plant tissues is discussed. With *Aphis rumicis* the phloem is an important source of the food supply but other tissues, including the cortex and mesophyll, may be drawn upon, particularly in the case of heavily infested plants.

LI. J. Davidson. "*Factors which Influence the Appearance of the Sexes in Plant Lice.*" Science, 1924, p. 364.

A short discussion of the observations of Marcovitch on this subject, in relation to results obtained in experiments at Rothamsted.

LII. H. M. Morris. "*Note on the Wheat Bulb Fly.* (*Leptohylemyia coarctata*)." Bulletin of Entomological Research, 1925. Vol. XV., pp. 359-360.

The method of control of this pest is based on the assumption that the eggs are laid in the bare or partially bare soil away trom the wheat. A recent examination of the soil fauna of the mangold plots of Barn field at Rothamsted has resulted in the discovery of a number of eggs of this insect. This observation affords confirmation of the recent work of Gemmill who first recorded the finding of eggs in field soil in Scotland.

LIII. F. Tattersfield and H. M. Morris. "*An Apparatus for Testing the Toxic Values of Contact Insecticides under Controlled Conditions.*" Bulletin of Entomological Research, 1924. Vol XIV., pp. 223-233.

This apparatus for determining the relative toxicities of contact insecticides is so arranged that successive batches of insects are sprayed under conditions as similar as possible, so that on using various substances at different concentrations, the results are directly comparable. It consists of a glass jar containing in its lid an atomiser, through which is projected by means of compressed air at known pressure a constant quantity of fine spray upon insects placed in a dish inside the jar. Examples are given of results obtained when different concentrations of nicotine are sprayed upon apterous agamic females of *A. rumicis.*

Two notes from the Statistical Department at Rothamsted are included, one analysing the accuracy with which the instrument sprays, and the other giving reasons for regarding the concentrations which kill 50 per cent. of the insects sprayed as the most suitable for the direct comparison of the toxicity of insecticides.

LIV. F. Tattersfield, C. T. Gimingham and H. M. Morris. "*Studies on Contact Insecticides.*" *Part* 1. *Introduction and Methods. Part 2. A Quantitative Examination of the Toxicity of* Tephrosia Vogelii, *Hook.* to Aphis Rumicis, L. (*The Bean Aphis*). Annals of Applied Biology, 1925. Vol. XII., pp. 61-76.

This paper deals in detail with the insecticidal properties of *Tephrosia Vogelii*, Hook., which, with other species of this genus, occurs abundantly in many parts of the world. The aqueous and alcoholic extracts of its leaves and seeds are shown to be highly toxic to *Aphis rumicis, L.,* the toxicity of the alcohol extract being of the same order as that of nicotine. Extracts of the stems have not proved so poisonous.

The plants of the genus Tephrosia seem to offer possibilities for practical use as insecticides.

LV. F. Tattersfield, C. T. Gimingham and H. M. Morris. *"Studies on Contact Insecticides." Part 3. A Quantitative Examination of the Insecticidal Action of the Chlor-, Nitro-, and Hydroxyl Derivatives of Benzene and Naphthalene.* Annals of Applied Biology, 1925. Vol. XII., pp. 218-262.

The toxicities of a number of chlor-, nitro- and hydroxyl derivatives of aromatic hydrocarbons to *Aphis rumicis, L.* (adults) and to *Selenia tetralunaria*, Hufn. (eggs) have been determined.

The order of toxicity to aphides of the hydrocarbons and their chlor- and nitro-derivatives is benzene < toluene < xylene < mono-chlor-benzene < p-dichlorbenzene < o-dichlorbenzene < tri-chlor-benzene < nitro-benzene < m-dinitrobenzene. The mono-chlor-nitro-benzenes have about the same toxicity as nitro-benzene; 1.-chlor-2.4-dinitrobenzene is slightly less toxic than m-dinitrobenzene.

Phenol and the three isomeric cresols are toxic to aphides only at high concentrations. The mono-nitro-phenols and cresols are all more toxic than the parent substances, the order of toxicity of the phenols being o-nitro phenol < m-nitro phenol and p-nitro-phenol < 2.4 dinitro phenol which is greater than tri-nitro phenol; the same order applies to the cresols and their corresponding derivatives.

a-chlor naphthalene proved to be the most toxic of the napthalene derivatives tested.

With few exceptions, the relative toxicities of the various compounds to the insect eggs are approximately in the same order as to the aphides. The nitro-derivatives of phenol and the cresols were specially studied and it was shown that, as in the case of aphides, the dinitro compounds are more toxic to eggs than either the mono- or the tri-nitro compounds.

The toxicity of 3.5 dinitro-o-cresol to adults of *Aphis rumicis* and to the eggs of *Selenia teralunaria* is of the same order as that of Nicotine.

Some of the compounds tested, although injurious to foliage, may prove of value as winter spray fluids for trees in a dormant condition and experiments on a practical scale are in hand.

No simple generalisation as to the correlation of toxicity with any one chemical or physical property seems possible in the present stage of our knowledge. It is probable that the nature of the toxic activity depends on chemical constitution, while the intensity of activity is determined by one or more physical properties.

See also paper LXXV.

(*b*) FUNGUS PESTS AND THEIR CONTROL.

LVI. Mary D. Glynne. *"Infection Experiments with Wart Disease of Potatoes,* Synchytrium Endobioticum *(Schilb.)."* Annals of Applied Biology, 1925. Vol. XII., pp. 34-60.

A study of certain conditions controlling infection of potatoes by the winter sporangium of *Synchytrium endobioticum* in the soil and by the summer sporangium in the laboratory has been made with a view to finding a reliable method of pot experiment

to serve as a basis in soil sterilisation research, and a method for testing immunity or susceptibility more rapidly than is at present done in the field. Experiments on infection by the winter sporangium in the soil have shown that a very high degree of soil moisture is necessary to ensure infection, but this need not be present during the whole of the growth period. It appears most effective when the wet period is in the second month. A high percentage infection is obtained in potato plants grown in soils of very varying physical character. Under the conditions of pot experiments the wart disease organism survives in the soil in the absence of the potato plant for a period of at least a year. There appears to be a dormancy period of about six weeks between soil infection and sporangial germination. The relation of numbers of sporangia in the soil to the incidence of disease is discussed. When favourable conditions were maintained 80-100 per cent. of the plants tested were found to be infected within a period of three months, even in varieties which in the field appear least susceptible. Under conditions less favourable to infection the relative susceptibilities of the several varieties become clearly marked. No wart disease was found under any conditions on immune varieties. Infection of various plants other than the potato was attempted. Small warts were found on three varieties of tomato and on *Solanum nigrum* and *S. dulcamara,* but none on five other varieties of tomato, on *Datura Stramonium, Salpiglossis sinuata, Hyoscymus niger, Atropa belladonna, Lycium chinense* or on many common weeds grown in infected soil.

A method is described for infecting sprouting tubers with wart disease by means of summer sporangia. Susceptible varieties subjected to this treatment develop young warts within three weeks, while immunes remain clean. The method can therefore be used for testing immunity or susceptibility in the laboratory.

LVII.—W. A. Roach, Mary D. Glynne, Wm. B. Brierley and E. M. Crowther. *"Experiments on the Control of Wart Disease of Potatoes by Soil Treatment with Particular Reference to the use of Sulphur."* Annals of Applied Biology, 1925. Vol. XII., pp. 152-190.

As susceptible varieties of potato are still widely cultivated and sporadic outbreaks of wart disease are a serious menace, it was imperative to find a method whereby the winter sporangia of *Synchytrium endobioticum* in contaminated soil could be killed. Previous studies and the unusual difficulties presented by the problem are discussed. Results of experiments extending over four years are recorded.

During 1921-2 pot experiments were carried out to test various chemicals both alone and in conjunction with steam. Steaming the soil proved effective in eliminating the disease, but it offered little hope of being economically possible as a field treatment. The amount of disease was reduced by sulphur, calcium and potassium polysulphides, formaldehyde, dichlor-

cresol, chlordinitrobenzene and nitrobenzene. Satisfactory infection was not obtained in pot experiments; this method was therefore abandoned in favour of field experiments.

The incorporation of chemicals with the soil in the field was carried out with the Simar Rotary Tiller, great care being taken to ensure very thorough and even distribution. Results suggest that the efficiency of the treatment depends on this thoroughness of incorporation. During 1922 a selection of the chemicals tried in 1921 and others were tested. From these sulphur was selected in 1923 for more extensive study as being the most hopeful because of its efficiency and cheapness.

In 1924, a year of very heavy disease, it was proved at Ormskirk that when the dose of ground sulphur was increased through 1, 2, 3, 4, 5, 10 cwts. per acre the degree of infection was reduced in direct ratio from 73 per cent., the value for untreated soil, to 8 per cent. for an application of 10 cwts. per acre. Doses greater than the latter did not produce proportionate decreases of infection; but there are reasons for thinking that this small amount of disease in certain of the plots was due to recontamination of those plots later in the season. When the results are represented in graphical form the straight line of nearest fit to the experimental values cuts the horizontal axis at a point representing 11.2 cwts. per acre of sulphur; and, in the absence of secondary infection, this quantity of sulphur should be slightly more than the minimum necessary to free the Ormskirk soil of disease.

On the heavy clay soil at Hatfield it was found necessary to use much heavier applications of sulphur (about 40 cwts. per acre) to ensure absolutely clean plots.

Gasworks-spent-oxides, tried as an alternative source of sulphur, proved rather less effective than ground sulphur when equal quantities of sulphur were applied in each case. The result was probably due to the unsatisfactory state of division of the sample of spent oxides.

Sulphur inoculated with *Thiobacillus thiooxydans* showed no increased efficiency over uninoculated sulphur on Ormskirk soils and appeared less effective than the latter on the Hatfield clay.

The elimination of wart disease in the field by sulphur and sulphur compounds was not correlated with the degrees of acidity produced and it would appear that some sulphur product other than sulphuric acid is the active fungicidal agent.

The sulphur treatment will be put to a large scale critical test in 1925-6; but the results to date seem to show that a feasible method of eradication of Wart Disease from contaminated land may have been found.

Many outbreaks are in gardens or allotments situated in the midst of rich potato districts; but owing to legislation limiting the movement of potatoes from relatively large areas surrounding these outbreaks, they are the cause of great losses to neighbouring growers. Hence it is economically possible to spend relatively large sums of money in dealing with these small outbreaks which would be out of the question if treatment at a proportionate cost were to be applied to larger areas. The results described in

this paper hold out definite hope of the financial possibility of the treatment of small isolated areas and offer some hope even of the possibility of applying such treatment to large areas.

(*c*) PLANT PATHOLOGY.

LVIII. WM. B. BRIERLEY. "*The Relation of Plant Pathology to Genetics.*" Report of Imperial Conference of Botany, London, 1924. (Cambridge University Press.) pp. 111-119.

A critical discussion of the problem. Where disease is due to growth in unfavourable conditions the problem resolves itself into a study of the genetical qualities of the plant in relation to soil, climate, etc. Where disease is brought about by parasites a complete understanding of any particular case involves the genetic and physiological analysis of both host and parasites and the physical and chemical analysis of the conditions under which the host and parasites have developed and at present exist. Assumption of germinal stability by the plant breeder and of germinal instability by the microbiologist are antithetic and require deeper analysis. Immunity and susceptibility relationships are often confined to pure lines of host and physiological strains of parasites and alterations in external conditions may greatly modify the phenotypic expression of this relationship. The primary factors that determine the appearance of disease in any particular case are (1) the genetic qualities of host and parasite; (2) environmental conditions; (3) relative geographic distribution of host and parasite. An additional factor of importance is the relation of the hygiene of the host to the incidence of disease, the commonly held ideas on which are urgently in need of revision. Most of the past analytic work on the genetics of micro-organisms and the disease relationship needs revising in the light of the following: (*a*) the co-existence of distinct physiological strains in morphological units; (*b*) the possibility, and in certain cases probability, of very considerable genetic complexity and genetic segregation in micro-organisms. Genetic research on bacteria and fungi is incommensurable with that on the more evolved organisms which is the basis of present genetical theory and in the study of the former exact criteria and definite concepts are almost entirely lacking.

TECHNICAL PAPERS.

(*a*) SOILS AND FERTILISERS.

LIX. H. J. PAGE. "*The Chemistry of the Soil and of Crop Production,*" *in* "*Chemistry in the XXth Century.*" (Benn Bros., 1924.) pp. 225-242.

Following a foreword by Sir John Russell, the subject is discussed with special reference to the progress made since 1900, more particularly by British workers.

LX. B. A. KEEN. "*Soil Tilth in Relation to Mechanical Tillage.*" Agricultural Gazette, 1924. Vol. C., pp. 297-298.

An account of the work on soil cultivation being done in the Physical Department. (*See* p. 28.)

LXI. E. M. Crowther and W. B. Haines. *"An Electrical Method for the Reduction of Draught in Ploughing."* The Implement and Machinery Review, 1924. Vol. L., pp. 1003-5.

An account of the practical aspects of the work described in paper XXVI.

LXII. E. M. Crowther. *"The Determination of Lime Requirements."* Read before Agricultural Education Association, July, 1924. Agricultural Progress, 1924. Vol. II., pp. 80-84.

The practical aspects of work discussed in papers XXVII.—XXX.

LXIII. E. M. Crowther. *"The Soils of Tropical Africa."* Empire Cotton Growing Review, 1925. Vol. II., pp. 35-39.

In response to enquiries from cotton growing centres, this article summarises the information on the nature of laterite soils, and the general question of the relation of soil type to climate and topography. Suggestions are made for the collection of simple data, essential for the preparation of soil maps.

LXIV. H. J. Page. *"The Utilisation of Waste Products in Agriculture."* Journal of the Ministry of Agriculture. 1924. Vol. XXX., pp. 910-918.

An article dealing with the utilisation of waste products such as sewage, town refuse, seaweed, straw, and various industrial wastes as fertilisers.

LXV. H. J. Page. *"Annual Report on Soils and Fertilisers for* 1923." Society of Chemical Industry. Annual Reports on Applied Chemistry. 1924. Vol. VIII.

LXVI. H. J. Page. *"Annual Report on Soils and Fertilisers for* 1924." Society of Chemical Industry. Annual Reports on Applied Chemistry. 1925. Vol. IX.

LXVII. H. J. Page. *"Agricultural Chemistry and Vegetable Physiology."* Annual Reports of the Chemical Society. Vol. XX. 1924.

LXVIII. H. J. Page. Sections on *"Soils"* and *"Chemistry of the Living Plant,"* in "Biochemistry," by H. J. Page and J. C. Drummond. Annual Reports of the Chemical Society. 1925. Vol. XXI.

LXIX. E. J. Russell. *"Monthly Notes on Manures."* Journal of the Ministry of Agriculture. 1923. Vol. XXIX., pp. 944-948, 1043-1047, 1138-1141. 1923. Vol. XXX., pp. 554-557, 660-663, 756-758. 1924. Vol. XXXI., pp. 873-875.

LXX. H. V. Garner. *"Monthly Notes on Manures."* Journal of the Ministry of Agriculture. 1923. Vol. XXX., pp. 861-864. 1924. Vol. XXX., pp. 953-959, 1057-1061, 1160-1164. 1924. Vol. XXXI., pp. 79-85, 190-195, 672-677, 774-779.

LXXI. E. J. Russell. *" Soil Improvements."* Journal of the Ministry of Agriculture. 1924. Vol. XXXI., pp. 120-127.

" Soil Improvement: Fertilisers and their Use." Journal of the Ministry of Agriculture. 1924. Vol. XXXI., pp. 217-223.

(*b*) biological.

LXXII. A. D. Imms. *" The Gout Fly of Barley."* Journal of the Ministry of Agriculture. 1925. Vol. XXXI., pp. 1137-1140.

A review of present knowledge of the life-history of the Gout Fly based primarily upon researches carried out at Rothamsted by J. G. H. Frew (papers XLVIII., XLIX). It is pointed out that possible control measures lie in early sowing and suitable manuring of the crop and that no remedial measures are available.

LXXIII. P. H. H. Gray. *" Bacteria of the Soil, and the Utilisation of Organic Antiseptics."* Discovery. 1923. Vol. IV., pp. 153-156.

An account of the isolation and distribution of soil bacteria that can decompose phenol, cresol, toluene and naphthalene.

LXXIV. P. H. H. Gray. *" Bacteria of the Soil, and the Decomposition of Cellulose."* Discovery. 1925. Vol. VI., pp. 56-59.

Promising methods of preventing losses that follow the incorporation of cellulosic materials into the soil are discussed in relation to recent knowledge of cellulose decomposition.

LXXV. F. Tattersfield and C. T. Gimingham. *" Experiments with* Sodium Fluosilicate *as an Insecticide."* Journal of Industrial and Engineering Chemistry. Vol. XVII., p. 323.

Preliminary experiments with Sodium and Potassium Fluosilicate as stomach poisons to caterpillars indicate that these compounds have interesting possibilities as insecticides.

(*c*) general.

LXXVI. E. J. Russell. *British Association for the Advancement of Science.* 1924. Presidential address, Section M.

LXXVII. E. J. Russell. " La relation entre les organismes du sol et sa fertilité." 1923. Troisième Congrès de Chimie Industrielle, Paris.

LXXVIII. B. A. Keen. *" Experiments Upon the Wheat Crop at Rothamsted."* Essex Farmers' Journal. 1923. Vol. II., pp. 140-142.

LXXIX. B. A. Keen. *" Recent Work at the Rothamsted Experimental Station."* Essex County Farmers' Union Year Book. 1924.

BOOKS PUBLISHED DURING 1923-4.

J. Davidson. "*A List of British Aphides*" (including notes on their synonymy, their recorded distriution and food-plants in Britain, and a food-plant index). Longmans, Green & Co. (in the press).

This work has been prepared owing to the great economic importance of aphides in relation to farm, garden and orchard crops, and their possible association with so-called mosaic diseases. Buckton's *Monograph on British Aphides* was published about 45 years ago, and since that time many more species have been recorded and the nomenclature has undergone drastic changes.

In the present work the species are placed in accordance with the more recent nomenclature. It is divided into four sections. Section 1 deals with the species in alphabetical order together with their food-plants and distribution in Britain. Section 2 deals with the genera, including critical notes. Section 3 is a food-plant index, forming a key to Section 1, and Section 4 a bibliography of 360 titles.

The work is intended to be a reference list and to serve as a general guide to the identification of the species of aphides.

R. A. Fisher. "*Statistical Methods for Research Workers*." Oliver and Boyd, Edinburgh (in the press).

The wide increase in the employment of statistical methods, especially in scientific research, has been accompanied by exceptionally rapid progress in recent years in the solution of the mathematical problems which confront the statistician. Most of the mathetical problems which confront the statistician. Most of the mathematical researches of the author have been undertaken in direct response to the needs of the laboratory worker, and with a view to the development of statistical methods adequate to the practical requirements of biological and agricultural research.

The aim of the book is to provide the non-mathematical scientific worker with the detailed application of precise statistical methods, which have been available hitherto only in specialised mathematical publications. The methods are illustrated throughout with numerical examples, drawn from recent scientific literature, giving the methods of computation in detail. New mathematical tables have been specially calculated for rendering the crucial tests simple and exact.

THE CROP RESULTS.

OCTOBER, 1922, TO SEPTEMBER, 1923.

The outstanding features of the season October 1922 to September 1923, were the sunless spring and the earliness and severity of the autumn frosts of 1923.

The year commenced favourably; October was unusually dry; it had the lowest rainfall figures for this month (0.787in. against an average of 3.06in.) since our records began, so the ploughing and drilling were got well forward. The dry weather continued into November, and with the help of night frosts which

broke down the newly turned furrows, everything was in favour of winter sowing. December was fairly mild; the first part of the month was dry but the second half was very wet, there being nearly 3in. of rain during this period. This precipitation, although unwelcome at the time, added appreciably to the stores of underground water, which had been seriously depleted by the drought of 1921, and not restored by the rainfall of 1922. Winter corn looked well and the young clover still maintained a satisfactory plant. January 1923 was dry, only 1.50 in. of rain being registered against an average of 2.41in. for this month. The sunshine and mean air temperature were both above the average, but the ground temperatures were not, and seventeen ground frosts were experienced in this month.

A change came in February. There was more than double the normal rainfall and the month was practically lost as far as field work and threshing was concerned. The wet spell continued into March, and not until its last few days could work on the land be resumed. The weather had not been unduly cold; the mean air temperature was, in fact, above the average both for February and March. Wheat and oats had made no progress in the sodden conditions of the two months, but when the water got away, they tillered out rapidly. A dry and dull April saw most of the spring sowings made under favourable conditions, a warm spell at the end of the month giving the barley a good start. May was drier than usual, but cold sunless weather set in with occasional frosts. The barley kept going better than might have been expected, but clover coming into bloom was severely checked. June was a month of warm droughty weather although actually duller than either April or May—the hours of bright sunshine being no less than 86 below the monthly average. The deep rooting crops came on fairly well, but barley gave signs of needing rain before the month was out. For each of the five months, February-June inclusive, there had been a deficiency of sunshine which amounted on the average to no less than 1½ hours per day. Naturally the soil temperature was lower than usual, and although the rainfall had not been high, the evaporation was reduced because of the lack of sunshine, and this led to a slightly greater percolation of water through the 60in. gauge. Warmer and much brighter weather came in July, the nights being for the first time warm. The striking feature of the month was the exceedingly heavy thunder showers on the night of the 9th, which, with the falls occurring on the following day, brought down 2¼ ins. of rain. Fortunately, our corn was not lodged, although elsewhere heavy crops of oats were badly laid over a wide area in the track of the storm. Hay was got in under good conditions and crops were satisfactory: the clover hay averaged 28 cwts. per acre over the farm and meadow hay yielded 35 cwts. on the manured land of Great Field. August was the best month of the year. The daily average of 11 hours of sunshine for the first fortnight caused some wilting of the shallow rooted crops, but refreshing rains came later in the month. The harvest weather was perfect for oats and wheat, but a little rain fell

before the barley was cut. The Broadbalk field was cleared by August 28th, and stubble cultivation was put in hand at once. Wheat yielded satisfactorily on Great Knott field, where it had been well done (37½ bu.), but on Great Harpenden field, where the record root crops of the previous year had exhausted the land, the yield was disappointing (24 bu.). Oats did fairly well and proved responsive to manures, a dressing of 1 cwt. of sulphate of ammonia and 2 cwt. of superphosphate increasing the crop from 26.4 bu. to 37.3 bu. per acre; while 2 cwt. sulphate of ammonia and 2 cwt. superphosphate pushed up the yield to 46.5 bu. The barley suffered from the drought in June, and the extraordinary lack of sunshine in spring and early summer: it yielded as well as could be expected—40 bu. on the better land, and 32 bu. on poorer tilths—while the quality was good and distinctly better than in 1922.

September was a favourable month, harvest was completed and ploughing continued. October set in wet, however, and 1¾in. of rain was recorded in excess of the average. Root lifting was badly hindered, and the hand digging of potato plots was exceptionally slow and difficult. November brought cold drying weather, and frosts occurred on 23 nights during the month. They were exceptionally severe on the nights of the 25th and 26th, when 18 and 19 degrees of frost respectively were recorded on the grass: practically all unharvested mangolds and potatoes were lost.

In spite of the lack of sunshine, the mangolds on Barn field did well and exceeded their average yield, but a large number of the plants rotted. Swedes, in spite of adequate manuring, were only a fair crop (14 tons); a good plant was obtained, but the bulbs failed to fill out. The sheep on the grazing plots did well; there was plenty of keep and bigger live weight increases per acre were obtained than in either of the previous seasons.

OCTOBER, 1923, TO SEPTEMBER, 1924.

The season 1923-24 was distinguished by its wetness and by one of the most protracted harvests of recent years. The rainfall of 36.51in. exceeded the average by 7.96in., only two wetter seasons (1903 and 1912) having been recorded since readings were commenced at this station in 1853. It is interesting to note that the twentieth century, though only in its early stages, has already produced three years that have been wetter than anything known to the Victorians—wetter even than the notorious year, 1879. Under the wet conditions, weeds got ahead, in many cases smothering the legitimate crop, and produced one of the foulest seasons for many years.

The season opened badly for farm work. October was very wet and drilling was hindered. The frosts and dry weather of November enabled all the winter corn to be sown by the 21st, but December and January were both difficult months for late sown cereals; very little flag was made and there was a loss of plant. The land was saturated with water and impossible to

work until the hard dry weather of February, with a rainfall of 0.714in. only, against the 71 year average of 1.889in. for this month, brought the furrow into a splendid condition for the spring working. The complete change in the soil condition effected by the February weather is well illustrated by a comparison of the drain-gauge figures for this month and January. In January the drainage through all three gauges was in excess of the rainfall in consequence of the saturated state of the soil in December and the early snow-drifts on the gauges in January : the rain was 2.90in. and the drainage (60in. gauge) 3.20in. ; while the February rain was 0.71in. and the drainage (60in. gauge) only 0.09in. Only 12.2 per cent. of the rain had percolated in February against an average of 75 per cent. for this month. However, the dryness of the February brought no relief to the struggling cereal crops.

The weather in March was well suited to cultivation : there were long spells of brilliant sunshine (no less than 56 per cent. over the average), a low rainfall, but with ground frosts each night except for a period of six days towards the end. In consequence barley was drilled under particularly favourable conditions in the latter half of the month. This was a general experience, many heavy land farmers never having seen spring corn go in so well. The frosts continued beyond the middle of April, and made the spring one of the latest within living memory. Later in April came milder and better weather; clover began to fill up after the long winter, barley made a good start, but winter corn was still backward, and oats in particular had lost much plant. With May the ground became much warmer, and by the end of the month the 12in. soil thermometer had risen by 10° F. to 58.8° F. May was, however, persistently wet. There were only 7 days on which no rain fell, and the total fall of 4.63in. was 2.58in. in excess of the monthly average. Weeds grew fast in the corn, and barley was checked by the wet conditions and the lack of sunshine. Rain continued during the first half of June and seriously interfered with hoeing, the very foul condition of Broadbalk being largely due to this cause. The second half of the month was warm and less wet. Clover promised excellent crops all over the farm, but some had been laid by the storms. Grass was growing too fast for the sheep on the grazing plots, although the stocking was heavier than in previous years. The first half of July contained the only period during the whole year that could properly be described by the name of summer—the nine days, July 8th-16th. The backward plants of wheat came on surprisingly well and gave promise of a fair crop. Hay making proceeded without any serious check, the coming of the fine spell at hay time being one of the few good features of the season. Crops were large, the unmanured meadow hay on Great field yielding 32 cwt., while the clover on Long Hoos averaged 42 cwt. per acre.

With the passing of the 9 fine days wet weather set in again; the aftermaths freshened up rapidly and regular plants of swedes and mangolds showed excellent promise although the mangolds needed sun.

August, though not wetter than the normal, was showery and sunless; ripening of the cereals was slow and uneven and cutting was later than usual. Wheat continued to improve, but weeds got ahead and filled up the bottom of the crop. September did nothing to improve what promised to be a difficult harvest; the rainfall of 3.42in. was nearly 1in. in excess of the average and there was little sunshine or drying weather. The bulk of the harvest was secured during the month, but much was in bad condition for early threshing. October, with 4.28in. of rain, had more than the normal rainfall by 1.14in., and with the shortening days and damp misty weather the labour involved in securing the remainder of the harvest was excessive. Cutting finished on October 17th.

Although wheat and barley were not much below the average in yield, the quality was poor and much of the barley was fit only for feeding purposes. Winter oats had lost much plant in the severe weather; they became very foul in summer and yielded badly.

Swedes and potatoes promised big yields, and in spite of the dull weather, the mangolds on Barn field were up to the average. The digging of potatoes and the lifting of the roots was in no way helped by the weather, for both November and December were considerably wetter than the average. On the other hand the absence of serious frosts enabled the roots to be got in without loss. Swedes with complete artificials yielded 26 tons per acre, second only to the excellent crop of 1922. Potatoes yielded 9½ tons with dung and complete artificials, the crop being practically free from disease, although a rather large proportion of the produce was of seed size.

It was commonly complained that the year was sunless, but in this respect it was over its full course no worse than usual: for the whole of the calendar year the deficiency from the average was only 50 hours. The unfortunate character of the season was its persistent wetness. From July 17th to the end of the year there were only two occasions (August 10th and 11th) when the state of the ground at 9 a.m. was recorded as dry; on all other mornings it was wet or damp. The previous year was by no means sunny, yet the ground was recorded as dry on 24 occasions in the three months beginning on July 17th.

WOBURN EXPERIMENTAL FARM.

REPORTS FOR 1923 & 1924 BY DR. J. A. VOELCKER.

SEASON 1923.

A late harvest made cultivation of the land backward, but open and fairly dry weather in October and November gave favourable conditions for sowing winter crops. This continued throughout December and January, rainfall not being excessive and frost nearly absent. The whole winter, 1922-3, indeed, was marked by absence of frost. February and March were wet months, and the soil was left in somewhat sticky condition for spring sowing. April, May and June were all cold and unseasonable, with absence of sunshine and late frosts in May, and crops made but little progress. About June 25th a spell of very hot and dry weather set in, giving good conditions for hay-making, though the yield was small. A violent thunderstorm in July with heavy rainfall saved the swede and other root crops, and also clovers and "seeds," which were beginning to show the effect of the drought; corn crops also grew rapidly. The fine weather continuing until August 14th, oats and wheat were safely reaped, and good crops of roots and aftermath (clover and "seeds") were promised. The drought had a bad effect on spring-sown corn crops, the first shoots ripening prematurely, and, when the rain came, fresh shoots were sent up which never developed properly. The general result was to give an exceedingly poor corn yield, and the weights at threshing were even less than the appearance in the field had indicated. The early-sown barley ripened well, but the late-sown was practically a failure. On August 14th there was a severe thunderstorm, during which 1½ inches of rain fell, and, the remainder of the month proving cold and showery, the harvesting of barley was delayed until August 31st.

The total rainfall for the 12 months to September inclusive was 23.2 inches, there being 175 rainy days. The heaviest rainfall was in July, viz., 3.53 inches, February giving 3.03 inches, August and September 2.94 and 2.48 inches respectively.

SEASON 1924.

The season 1923-4 was an altogether exceptional one. Heavy rainfall and long continued absence of sunshine and warmth combined to retard the growth of corn crops and to prevent their proper maturing. Weeds spread rapidly, and it was difficult to keep the land clean. Under these conditions only poor yields of low quality corn could be expected, especially as harvesting took place in bad weather.

The rainfall for the whole season, October 1923 to October 1924, was 30.30 inches as against 23.2 in 1923, with 201 rainy days (over .01 inch) against 175 in 1923. May—just the time when dryness and warmth were required—was by far the wettest month of the whole year, with 6.06 inches of rain, and 20 rainy days. On the other hand, February was the driest month, with only 0.48 inches of rain—in February, 1923, it was 3.03 inches.

The harvest months of July, August and September were alike wet, with 3.07, 2.32 and 3.17 inches of rain respectively.

The untoward weather influences were felt in very marked measure on the continuous wheat and barley plots, the returns for which were lower than for many years past. The highest yield of barley on the continuous plots was only 13 bushels per acre, whereas land close by in the same field gave, under rotation cropping, 27.3 bushels per acre where no nitrogen but only mineral manures had been applied.

Great difficulties also were experienced with the root crops, through the excessive washing of the soil and the floods that came in the latter part of May. One field was under water for some days, and in another the newly-planted potatoes were, in places, washed out and carried some distance away. The lucerne inoculation experiment was ruined by the flooding, and had to be abandoned. A great deal of the manure put in the land for the root crops must have been washed out, and so caused a diminution in the returns.

The one really good crop was hay—alike from rotation grasses, clover and from permanent pasture—and abundant crops were gathered in excellent condition.

FIELD EXPERIMENTS.

1. *Continuous Growing of Wheat* (Stackyard Field), 1923.

1923 (47*th Season*).

"Red Standard" wheat, 2½ bushels per acre, was drilled on October 26th, 1922, farmyard manure having been ploughed in on 11b on October 19th and 20th, while mineral manures (phosphates and potash) were applied just previously to the sowing of the wheat, and rape dust (plot 10b) on November 14th. Nitrogenous top-dressings of sulphate of ammonia and nitrate of soda were given on May 15th and June 20th, 1923.

The wheat was cut on August 13th, stacked August 21st, and threshed November 14th, 1923.

The yield was exceptionally poor, the unmanured produce averaging 5.6 bushels of corn and 7 cwt. of straw per acre, against 8.5 bushels and 7.25 cwt. in the previous year. One has to go back to 1914 to find so bad a yield on these plots, the return for these two years being, indeed, very similar. Added to the difficulties of season was the fact that the damage done by pheasants to some of the normally weak plots was so great that they had to be resown later with spring wheat. This never came up satisfactorily and, for purposes of comparison and comment, the ammonia plots must be left out of account.

1924 (48*th Season*).

"Red Standard" wheat, at the rate of 3 bushels per acre, was drilled on October 19th, 1923, plot 11b having received its farmyard manure and plot 10b its rape dust on October 16th, and mineral manures having been given to the other plots to receive them, on October 18th. The nitrogenous top-dressings were applied, the first halves on May 5th-6th, 1924, and the second

Continuous Growing of Wheat, 1923 (47th Season) and 1924 (48th Season).

(Wheat grown year after year on the same land, the manures being applied every year.)

Stackyard Field—Produce per acre.

Plot.	Manures per acre.	1923. Head Corn. No. of bushels.	1923. Head Corn. Weight per bushel.	1923. Tail Corn. Weight.	1923. Straw, Chaff, &c.	1924. Head Corn. No. of bushels.	1924. Head Corn. Weight per bushel.	1924. Tail Corn. Weight.	1924. Straw, Chaff, &c.
			lb.	lb.	cwt. q. lb.		lb.	lb.	cwt. q. lb.
1	Unmanured	5·2	62·0	4	5 0 6	1·8	56·0	2	4 1 4
2a	Sulphate of Ammonia (=25 lb. Ammonia)	—	—	—	—	—	—	—	—
2aa	As 2a, with 5 cwt. Lime, Jan., 1905, repeated 1909, 1910, and 1911 ...	6·0	61·5	8	8 2 0	3·6	55·0	4	9 0 0
2b	As 2a, with 2 tons Lime, Dec., 1897	2·0	60·0	10	2 0 24	2·7	56·0	2	5 1 4
2bb	As 2b, with 2 tons Lime repeated Jan., 1905	3·4	61·7	6	4 3 12	6·6	56·5	4	9 1 4
3a	Nitrate of Soda (=50 lb. Ammonia)	11·7	61·5	8	10 3 4	15·0	56·0	4	18 2 4
3b	Nitrate of Soda (=25 lb. Ammonia)	10·6	61·7	8	9 2 12	14·3	56·0	12	18 0 20
4	Mineral Manures (Superphosphate 3 cwt., Sulphate of Potash ½ cwt.) ...	8·9	61.0	4	9 2 4	3·5	57·0	4	5 3 14
5a	Mineral Manures and Sulphate of Ammonia (=25 lb. Ammonia) ...	1·5	60·0	4	2 0 24	4·0	56·0	4	7 3 20
5b	As 5a, with 1 ton Lime, Jan., 1905	6·4	61·5	8	7 1 16	6·4	55·5	2	10 0 0
6	Mineral Manures and Nitrate of Soda (=25 lb. Ammonia)	13·0	61·0	6	11 1 0	15·2	55·5	11	20 3 10
7	Unmanured	6·1	62·2	7	5 3 2	1·4	56·0	2	4 2 2
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia (=50 lb. Ammonia)	1·5	62·0	8	2 0 8	—	—	—	—
8aa	As 8a, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	2·8	61·5	8	5 1 12	6·8	56·0	4	16 3 12
8b	Mineral Manures, Sulphate of Ammonia (=50 lb. Ammonia) omitted in alternate years	1·2	62·0	4	2 8	—	—	—	—
8bb	As 8b, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	6·4	60·0	12	6 2 24	4·0	56·0	4	8 3 4
9a	Mineral Manures and, in alternate years, Nitrate of Soda (= 50 lb. Ammonia)	10·0	60·5	10	9 4 24	14·5	56·7	12	21 3 20
9b	Mineral Manures, Nitrate of Soda (= 50 lb. Ammonia) omitted in alternate years	3·8	60·5	4	3 2 24	5·5	56·0	3	11 4 16
10a	Superphosphate 3 cwt., Nitrate of Soda (=25 lb. Ammonia)	11·9	61·5	8	12 1 20	16·7*	56·0	16	24 1 12
10b	Rape dust (=25 lb. Ammonia)	8·8	61·5	12	10 0 16	9·5	57·2	8	15 0 24
11a	Sulphate of Potash 1 cwt., Nitrate of Soda (=25 lb. Ammonia)	10·5	62·0	8	10 1 20	18·0*	54·5	18	31 2 0
11b	Farmyard Manure (=100 lb. Ammonia)	11·7	62·0	12	14 1 24	17·5	54·1	30	32 3 24

* Nitrate of Soda = 50 lb. Ammonia was, in error, applied in 1924 to plots 10a and 11a.

halves on June 18th. The wheat, though it came up quite well, was, for a considerable time afterwards, almost at a standstill, and was late in making a start. It looked better in January, 1924, but another period of stagnation occurred in March and April, and the crop moved but slowly. In June the farmyard manure plot (11b) looked the best; it was also specially noticeable that the nitrate of soda plots were better than the sulphate of ammonia ones, but much more weedy than any of the other plots. The crops being but small, stood up well and were cut on August 14th, carted on September 2nd and stacked, being threshed out the week before Christmas, 1924.

The produce, on account of the untoward conditions, was very poor—as low as any recorded during the whole 48 years. The unmanured produce was only 1.6 bushels of corn with 4 c. 1 qr. 17 lbs. of straw, etc., per acre; nitrate of soda was markedly superior to sulphate of ammonia throughout, but the heavier dressings were not better than the lighter ones. Lime still continued to show its influence, even in plot 2b (last limed in 1897).

The results for both years are given on page 79.

2. *Continuous Growing of Barley* (Stackyard Field).

1923 (47*th Season*).

Farmyard manure was applied (plot 11b) March 21st, 1923, mineral manures and rape dust on April 4th, and barley—"Plumage Archer"—at the rate of 2½ bushels per acre was drilled on April 5th. The first nitrogenous top-dressings were given on June 12th, the second on July 10th. On plot 2aa a further application of lime—10 cwt. per acre—was made in January 1923.

The season was very unfavourable for barley, and the crop was specially short in the straw. The farmyard manure plot (11b) was the only one to look even fair, and a small yield generally characterised the harvest which began on August 31st, the barley being stacked on September 1st and threshed November 11th, 1923.

The unmanured produce was only 3.9 bushels of corn with 6 cwt. 3 qrs. straw per acre, a yield below even the poor one of 1921. Nitrate of soda, both alone and with minerals, did much better than sulphate of ammonia, even when lime was given as well.

1924 (48*th Season*).

"Plumage Archer" barley, at the rate of 3 bushels per acre, was drilled on March 10th, 1924. Rape dust and farmyard manure had been previously (February 11th) applied to plots 10b and 11b. The barley was slow in coming up and was never more than a thin crop and not of good healthy colour; further, weeds were very abundant, especially on the nitrate of soda plots. The first top-dressings of nitrogenous salts were given on May 15th and 16th, the second on June 25th. A very poor crop only—as low as any during the whole 48 years' experiments—was obtained. This was cut on August 13th, carted and stacked on

Continuous Growing of Barley, 1923 (47th Season), and 1924 (48th Season).

(Barley grown year after year on the same land, the manures being applied every year.)

Stackyard Field—Produce per acre.

Plot.	Manures per acre.	1923. Head Corn. No. of bushels.	1923. Head Corn. Weight per bushel.	1923. Tail Corn. Weight.	1923. Straw, Chaff, &c.	1924. Head Corn. No. of bushels.	1924. Head Corn. Weight per bushel.	1924. Tail Corn. Weight.	1924. Straw, Chaff, &c.
			lb.	lb.	cwt. q. lb.		lb.	lb.	cwt. q. lb.
1	Unmanured	4·1	52·5	2	7 2 16	1·8	51·2	2	3 1 2
2a	Sulphate of Ammonia (=25 lb. Ammonia)	—	—	—	—	—	—	—	—
2aa	As 2a, with 5 cwt. Lime, Mar., 1905, repeated 1909, 1910 and 1912, and 10 cwt. Lime applied Jan., 1923	1·7	52·7	4	3 1 12	4·9	51·6	2	8 0 20
2b	As 2a, with 2 tons Lime, Dec., 1897, repeated 1912	3·2	52·0	4	5 2 8	4·1	51·0	4	5 2 12
2bb	As 2a, with 2 tons Lime, Dec., 1897, repeated Mar., 1905	3·3	51·0	2	6 0 0	3·6	49·8	2	6 1 12
3a	Nitrate of Soda (=50 lb. Ammonia)	11·1	51·5	12	14 0 0	5·0	50·5	4	8 3 20
3aa	As 3a, with 2 tons Lime, Jan., 1921	8·0	51·2	8	9 2 24	3·6	49·0	4	7 1 16
3b	Nitrate of Soda (=25 lb. Ammonia)	5·0	50·0	4	8 2 0	4·5	50·2	4	7 3 0
3bb	As 3b, with 2 tons Lime, Jan., 1921	4·8	51·0	2	8 1 8	4·6	50·0	4	8 2 12
4a	Mineral Manures[1]	5·8	50·2	4	5 2 10	2·1	49·8	2	3 1 6
4b	As 4a, with 1 ton Lime, 1915	6·1	51·2	6	8 0 12	4·6	50·0	4	3 2 4
5a	Mineral Manures and Sulphate of Ammonia (=25 lb. Ammonia) ...	2·2	51·7	4	3 1 12	—	—	—	—
5aa	As 5a, with 1 ton Lime, Mar., 1905, repeated 1916	6·2	51·5	8	8 1 4	10·8	50·5	8	10 3 8
5b	As 5a, with 2 tons Lime, Dec., 1897, repeated 1912	6·5	51·5	8	8 2 20	7·1	50·5	4	5 1 18
6	Mineral Manures and Nitrate of Soda (=25 lb. Ammonia)	8·5	50·5	4	10 3 10	13·0	49·4	12	9 3 2
7	Unmanured	3·7	52·0	4	6 0 10	1·6	50·5	2	3 1 25
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia (=50 lb. Ammonia)	—	—	—	—	—	—	—	—
8aa	As 8a, with 2 tons Lime, Dec., 1897, repeated 1912	8·7	52·0	8	8 1 4	13·9	51·0	4	10 3 12
8b	Mineral Manures, Sulphate of Ammonia (=50 lb. Ammonia) omitted in alternate years	—	—	—	—	—	—	—	—
8bb	As 8b, with 2 tons Lime, Dec., 1897, repeated 1912.	6·3	52·0	8	8 3 4	6·6	51·0	4	6 1 16
9a	Mineral Manures and, in alternate years, Nitrate of Soda (= 50 lb. Ammonia)	13·1	52·0	4	16 0 20	8·5	51·5	6	7 0 24
9b	Mineral Manures, Nitrate of Soda (= 50 lb. Ammonia) omitted in alternate years	5·9	52·5	2	9 0 0	5·7	51·0	6	4 3 6
10a	Superphosphate 3 cwt., Nitrate of Soda (=25 lb. Ammonia)	5·6	52·0	6	7 0 12	8·5	51·0	6	8 0 14
10b	Rape dust (=25 lb. Ammonia)	5·3	53·2	6	6 0 0	2·6	52·1	2	5 0 0
11a	Sulphate of Potash 1 cwt., Nitrate of Soda (=25 lb. Ammonia)	11·4	52·5	8	10 1 8	6·7	51·4	4	6 1 6
11b	Farmyard Manure (=100 lb. Ammonia)	21·8	53·0	8	18 0 0	13·0	52·0	6	9 0 18

[1] Superphosphate 3 cwt., Sulphate of Potash ½ cwt.

August 31st and September 1st, and threshed just before Christmas.

The unmanured produce was only 1.7 bushels of corn with 3 c. 1 qr. 14 lb. of straw, etc., per acre. Sulphate of ammonia by itself, or with minerals and no lime, as usual, gave no crop, but with lime gave marked increases, going up to a yield of 13.9 bushels per acre (plot 8aa). Nitrate of soda did not, on the whole, do as well as sulphate of ammonia with lime, the highest yield with it being 13 bushels (plot 6).

The heavier dressings of nitrate of soda had no advantage over the lighter ones, nor did the use of lime on the nitrate plots produce any benefit.

The results for both years are given on page 81.

3. *Rotation Experiments.*

The Unexhausted Manure Value of Cake and Corn (Stackyard Field).

1923. *Barley.*

(*a*) Series C.

As the swede crop of 1922 was quite small, mangels were carted on to augment the root supply. The sheep were on from December 20th, 1922, to February 7th, 1923. They consumed, on the corn plot (2 acres) 22 cwt. of oats and 10 cwt. of barley, equivalent to 29.25 lb. nitrogen per acre; on the cake plot (2 acres) 7 cwt. of linseed cake, 6 cwt. decorticated cotton meal and 14 cwt. 42 lb. of undecorticated cotton cake, equivalent to 67 lb. nitrogen per acre.

"Plumage Archer" barley, at the rate of 2½ bushels per acre, was drilled on March 28th, and a clover mixture—Red Clover 7 lb., Alsike 3 lb., Trefoil 3 lb. per acre—(red clover alone having been taken four years previously) was sown in the barley on May 1st, 1923. The barley grew fairly well in spite of the unfavourable season. The crop was cut on August 16th.

1924. *Clover.*

The clover grew well in 1924, promising an excellent crop. This was cut and gathered on June 27th—30th, 1924. The second growth was small and was ploughed in.

The results were :—

	Barley, 1923				Hay, 1924
	Head Corn		Tail Corn	Straw, Chaff, etc.	Yield per Acre
	Yield per Acre	Weight per bushel	Weight		
	bushels	lb.	lb.	cwt.	cwt.
Corn fed	14·2	55	21	9·7	38·7
Cake fed	16·2	55	28	10·1	37·1

Neither in the barley crop of 1923 nor in the succeeding clover of 1924 has there been anything to show the value of the richer cake-feeding as against that of corn. This result is

striking, as not only were the amounts of corn and cake much greater than previously used, but the margin between the cake and corn fed was nearly 38 lb. of nitrogen, equivalent to 2 cwt. of nitrate of soda per acre.

(*b*) Series D. 1923, *Clover.* 1924, *Wheat.*

Red clover had been sown in the barley crop of 1922 on May 22nd, and it looked very well through the winter. It was twice cut for hay in 1923, viz., on June 25th and on August 13th, and "Red Standard" wheat, 3 bushels per acre, was drilled October 18th. It came up fairly well, but was rather slow in growth. The cake-fed plot looked rather better than that corn-fed. The crop improved towards harvest and was cut August 26th and carted September 2nd. The results were :—

Clover, 1923				Wheat, 1924			
	Yield per Acre			Head Corn		Tail Corn	Straw, Chaff, &c.
	1st Cut	2nd Cut	Total	Yield per acre	Weight per bushel	Weight	
	cwt.	cwt.	cwt.	bushels	lb.	lb.	cwt.
Corn fed	34·0	13·5	47·5	19·3	54·0	20	13·2
Cake fed	35·1	13·3	48·4	19·5	55·8	20	16·0

The differences are not significant, but it must be remembered that no cake or corn had been fed since 1916.

4. *Green-manuring Experiments.*

(*a*) Stackyard Field. Series A.

1923.

As noticed in the 1922 report, a change in these plots was introduced in 1922, they being now so arranged that every year there will be a corn crop on one-half of the area and a green-crop on the other half.

Upper Half.—The green crops grown and fed off by sheep in July and October, 1922—1½ cwt. of cotton cake per acre being given as well—were followed by wheat—"Red Standard"—which was drilled on November 9th at the rate of 2½ bushels per acre. On December 15th 3 cwt. per acre of superphospate were given to the wheat. It was never more than a poor crop, but now, for the first time, the wheat after tares seemed to be better than that after mustard. It was cut August 13th, stacked August 21st, and threshed November 15th.

The results were :—

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.
		Yield per acre	Weight per Bushel	Weight	
		bushels	lb.	lb.	cwt.
1	After Tares fed off	8·0	62·3	9	9·3
2	After Mustard fed off ...	5·6	62·0	8	5·3

The crops were miserably small, and it is hard to understand how they came to be so, seeing that not only were two crops of tares and mustard respectively fed off on the land, but that 1½ cwt. of cotton cake per acre were given as well to the sheep. Yet a wheat crop of only 8 bushels per acre was the result. For the first time, however, in the history of the experiment, a slight superiority was shown with the tares as compared with the mustard, similarly fed.

Lower Half.—Here tares were drilled—2 bushels per acre—on November 3rd, 1922, and were fed off by sheep receiving also 3 cwt. cotton cake per acre (increased from the 1½ cwt. per acre of former years). It was only possible to take one crop of tares. Two crops of mustard, however, were grown, the seed being sown on May 4th, 1923, and on August 4th, at the rate of 20 lb. per acre. Each crop was similarly fed off with cake, and, after ploughing the land, wheat was sown.

1924.

On the upper half, green crops followed the wheat of 1923. Previous to their sowing, an application of two tons of lime per acre was given to one half of each acre plot—September 25th, 1923. Tares—2 bushels per acre were drilled on March 19th. 1924, and gave an excellent crop. Mustard—20 lbs. per acre—was sown broadcast on May 30th, and also grew well. Sheep were put on the mustard on July 22nd, and passed on to the tares on August 12th, consuming on each plot 3 cwt. per acre of cake (half linseed and half cotton cake). Only one green crop of each kind was grown, and after the sheep had eaten these off, the plots were ploughed up in October and wheat again sown.

On the lower half, wheat ("Red Standard") was drilled on November 5th, 1923, at the rate of 3 bushels per acre. It showed about the middle of December and grew well right on to May, 1924, the wheat after tares looking decidedly better than that after mustard, and being as good as, or even better than, any other wheat plot on the field. After this however came the usual falling off, and by the middle of June the wheat looked poor and short in straw on both plots. It was cut on August 14th, carted September 2nd, and threshed just before Christmas.

The yields were :—

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.
		Yield per Acre	Weight per bushel	Weight	
		bushels	lb.	lb.	cwt.
1	After Tares fed off	7·3	57·0	6·0	8·7
2	After Mustard fed off ...	9·1	57·7	6·5	9·5

Thus the old order of things—broken in 1923—was restored, the mustard once more showing itself the better preparation, though both crops were miserably and unaccountably poor, the wheat crop on Series D (Rotation) in the same field being 19.5 bushels per acre.

(*b*) *Lansome Field.*

On the extended area, now consisting of five plots, wheat followed the ploughing-in of the green crops, 5 cwt. of basic slag and 1 cwt. of sulphate of potash per acre having been previously (1921) given to these crops. "Red Standard" wheat—2½ bushels to the acre—was drilled on all the plots on October 25th, 1922. Throughout the period of growth the crop looked better on the tares plots than on the mustard ones, and these appearances were borne out at harvest. The crop was cut August 14th, stacked August 21st, and threshed November 12th, 1923.

The results were :—

		Head Corn		Tail Corn	Straw, Chaff, etc.
		Yield per Acre	Weight per bushel	Weight	
	Plot	bushels	lb.	lb.	cwt.
Old Plots	1. After Mustard ploughed in	6·9	63·0	8	8·9
	2. After Tares ploughed in ...	7·0	63·2	8	12·4
New Plots	3. After Mustard ploughed in	7·2	63·0	6	9·3
	4. After Tares ploughed in ...	7·2	63·2	6	13·9
	5. Control (no green crop) ...	5·7	63·2	4	8·6

The differences in weight of corn are but small, but the tares have, in each case, given appreciably more straw, and the general tendency is to confirm the results in Stackyard Field. At the same time, the crops are unaccountably small, and, following on work carried out with these soils in the Pot-culture Station, it was decided to lime one-half of each series in Lansome Field and Stackyard Field, and to see whether the small crops obtained might not be due to the poverty of the soils in lime.

1924.

Lime, as contemplated above, was given to one-half of all the plots on September 25th, 1923, at the rate of 2 tons per acre. Tares—2 bushels per acre—were sown on March 29th, 1924, and mustard—20 lb. per acre—on May 29th. The green crops were decidedly better on the new plots than on the old ones. They were ploughed in on July 31st and second crops sown on August 19th, these being, in turn, ploughed in green, September 26th-30th, and wheat sown.

5. *Malting Barley Experiments.*

1923.

The field chosen was Butt Close, a light sandy loam. The area used had previously carried a moderate crop of swedes, to which farmyard manure had been given.

The barley was drilled on April 10th at the rate of 2½ bushels per acre, the manures being put on the same day. The barley came up nicely and promised to be an excellent crop. Early in June the control, plot 1, looked a bit patchy, while plot 5 (no nitrogen) was much less vigorous than plots 2, 3 and 4. These appearances continued until July. The crop was cut and shocked August 30th-31st. Pots 2—5 were all dead ripe. Plot 1 had a fair proportion of green or only partially ripe straw.

1924.

The experiment of 1924 was in Stackyard Field, following oats. "Plumage Archer," as before, was drilled—3 bushels per acre—on March 11th, the various manures being applied at the same time. The barley grew well. The plot to ripen quickest was plot 2 (complete manuring), and the phosphate plot (3) ripened more quickly than the potash one (2).

The barley was cut on August 12th.

The yields generally were lower than in 1923 and the relative yields of the no-phosphate and no-potash plots are reversed in the two years. The results for the two years are given in the following table :—

Manures per Acre	1923				1924			
	Head Corn		Tail Corn	Straw, Chaff, etc.	Head Corn		Tail Corn	Straw, Chaff, etc.
	Yield per acre	Weight per bushel	Weight		Yield per acre	Weight per bushel	Weight	
	bushels	lb.	lb.	cwt.	bushels	lb.	lb.	cwt.
No Manure	35·1	53·3	9·5	21·0	22·5	52·9	22·0	11·2
Superphosphate 3 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1 cwt.	43·4	55·6	9·0	21 0	29 4	53·1	26·0	17·85
Superphosphate 3 cwt., Sulphate of Ammonia 1 cwt.	41·0	55·5	10·0	21·2	32 8	52·7	26·0	18·25
Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1 cwt.	38·8	55·0	10·0	17·75	38·8	53·5	30·0	21·45
Sulphate of Potash 1½ cwt., Superphosphate 3 cwt.	31·9	53·5	6·0	14·4	27·3	53 7	18·0	15·6

6. *Experiments with Sulphate and Muriate of Ammonia.*

Comparisons of these two manures were carried out in 1923 on wheat and barley and in 1924 on wheat, mangolds and swedes. The details of cultivation, etc., follow. In each experiment 1 cwt. of sulphate of ammonia and the equivalent quantity of muriate were employed :—

Wheat, 1923 : Road Piece, thin light sandy loam. Drilled, 2½ bushels per acre, October 23rd, 1922. Top dressings applied May 31st. Cut August 10th, the previous crop being "seeds," ploughed in. No basal manuring was given.

Barley, 1923 : Butt Close, light sandy loam. Drilled, 2½ bushels per acre, April 10th. Top dressing applied June 2nd. Cut August 30th. Previous crop, swedes fed off with sheep.

Wheat, 1924 : Great Hill, light sandy loam. Drilled, 3 bushels per acre, November 1st-2nd, 1923. Top dressing applied June 3rd. Cut August 15th-18th. Previous crop, red clover (cut twice).

Mangolds, 1924 : Warren Field, Oxford clay. Dung, 8 tons per acre, April 26th. Super, 2 cwt. and Kainit 3 cwt. per acre, May 13th, seed drilled 6 lb. per acre, May 15th. Top dressings applied July 22nd-23rd. Roots pulled November 15th-25th.

Swedes, 1924 : Warren Field, Oxford clay. Dung 12 tons per acre, May 10th-15th. Super 4 cwt. and Kainit 4 cwt., May 16th, seed drilled 5 lb. per acre, June 23rd. Roots pulled January 1st-23rd, 1925.

Note.—The swedes and mangolds experiments were subjected to heavy rainfall and flooding during May (p. 78).

The results follow :—

Crop	Plot	Produce per Acre: Head Corn: Yield per Acre	Produce per Acre: Head Corn: Weight per Bushel	Produce per Acre: Tail Corn: Weight	Produce per Acre: Straw, etc.
		bushels	lb.	lb.	cwt.
Wheat, 1923...	2. Control	15·6	61·0	17	11·3
	1. Sulphate of Ammonia ...	17·6	61·5	13	13·1
	3. Muriate of Ammonia ...	19·8	61·5	16	14·8
Barley, 1923...	2 Control	36·6	53·5	6	17·0
	5 Control	35·6	53·7	6	18·9
	1 Sulphate of Ammonia ...	41·6	53·7	9	19·9
	4 Sulphate of Ammonia	40·0	53·8	10	19·4
	3 Muriate of Ammonia ...	46·7	54·0	7	22·5
	6 Muriate of Ammonia	45·5	53·9	8	21·1
Wheat, 1924...	1. Sulphate of Ammonia ...	43·0	57·3	20	32·2
	2. Muriate of Ammonia ...	45·8	56·8	22	34·4
				Mangolds	Swedes
Mangolds and Swedes, 1924				Tons	Tons
	1. Dung and Minerals only			11·85	14·56
	2. Dung and Minerals with Sulphate of Ammonia			14·07	17·21
	3. Dung and Minerals with Muriate of Ammonia			12·85	15·76
	4. Dung and Minerals with Muriate of Ammonia			12·87	16·80

Although the differences in some cases are small, it appears that for corn the muriate gives a bigger yield than sulphate of ammonia, while the reverse holds for roots.

7. *The Relative Values of Lime and Chalk for Liming Purposes* (Stackyard Field). Series B.

1923.

This experiment—one conducted on the crops of an ordinary 4-course rotation—was started in 1919, when 12 plots in Stackyard Field, each one-sixth of an acre in extent, were set out in two series, the one consisting of plots to which caustic (burnt) lime was given in different quantities, the other of plots which received ground chalk in quantities supplying the same amount of lime (CaO) as given to the corresponding caustic lime plots. There were also two unlimed plots.

The lime and chalk were spread in January, 1919, and the land ploughed.

The crops were :—1919, barley; 1920, swedes; 1921, barley; 1922, tares followed by mustard; 1923, oats. The ordinary course of cultivation, manuring, etc., was followed over the whole area, the only difference being in the application of lime or of chalk.

It would naturally take some time for the lime and chalk to distribute themselves fairly over the soil; for the first few years there was little beyond the general indication that lime produced rather the better crop; this was the case with the swedes of 1920 and the barley of 1921; the tares of 1922 and subsequent mustard crop were fed off by sheep and not weighed. Black Winter oats followed as the crop of 1923, and were drilled on October 31st at the rate of 4 bushels per acre. The crop was cut August 2nd-3rd, stacked August 16th, and threshed November 12th and 13th, 1923.

The harvest results were as follows :—

Plot	Applications per acre	Head Corn		Tail Corn	Straw, Chaff, etc.
		Yield per acre	Weight per bushel		
		bushels	lb.	lb.	cwt.
1	No Chalk	22·1	38·0	3·5	8·5
2	Chalk = 10 cwt. Lime	19·9	39·0	2·5	7·3
3	,, = 1 ton Lime	20·6	37·5	3·0	7·6
4	,, = 2 tons ,, ...	24·9	37·2	3·5	8·7
5	,, = 3 ,, ,, ...	28·1	36·7	4·5	10·6
6	,, = 4 ,, ,, ...	26·2	36·5	3·5	9·0
7	No Lime	23·0	38·5	3·5	7·8
8	Lime, 10 cwt.	26·2	39·0	4·0	8·5
9	,, 1 ton	30·9	39·0	4·5	10·6
10	,, 2 tons	26·8	39·0	4·0	10·9
11	,, 3 ,, ...	31·1	38·5	3·5	11·1
12	,, 4 ,, ...	25·7	38·5	3·5	10·1

These results, taken as a whole, run very consistently, and point to what had been previously noticed, viz., that the lime series gave better crops than the chalk. Adding up the chalk series, a total of 141.8 bushels of corn is shown as against 163.7 bushels with the lime series. The duplicate unlimed plots are in very fair agreement. The lime series shows a more or less regular increase as more lime is added, up to 4 tons per acre, which latter amount would appear to be too much. With the chalk plots there is a similar, though not so marked, increase. The increase from lime is equally marked in the straw as in the corn.

It is worthy of remark that the exact duplicate of these observations is to be found in the pot-culture experiments on the same subject (see page 94).

Examining the stubble after harvest, it was noticed that, as the quantity of lime or chalk was increased, so the spurry became less and less prominent, and its absence was more marked on the limed plots.

1924.

After the oat crop of 1923 swedes were to follow. These were put in—June 12th—with 5 cwt. superphosphate and 1 cwt. sulphate of potash per acre, and came a fair plant. The lime plots looked, throughout, somewhat superior to the chalk ones. The roots will be weighed and then fed off on the land by sheep.

11. RAINFALL AT WOBURN EXPERIMENTAL FARM, 1923 and 1924.

(292 ft. above Sea Level.)

1922-23			1923-24		
Month	Total inches	No. of days with ·01 in. or more recorded	Month	Total inches	No. of days with ·01 in. or more recorded
1922			1923		
October	0·76	14	October	3·58	23
November	1·07	11	November	1·25	15
December	2·38	18	December	2·37	20
1923			1924		
January	1·28	13	January	2·25	21
February	3·04	25	February	0·48	12
March	2·10	17	March	0·69	9
April	1·50	12	April	2·71	13
May	1·63	17	May	6·05	20
June	0·53	10	June	2·33	15
July	3·52	12	July	3·06	17
August	3·02	12	August	2·31	17
September	2·48	12	September	3·17	19
Total	23·31	173	Total	30·25	201

POT-CULTURE EXPERIMENTS, 1923.

1. *The Hills' Experiments.* (*a*) Lead Chloride. (*b*) Uranium Compounds.

(*a*) Lead Chloride.

In 1922, work with different compounds of lead had shown that, for wheat, 1% of lead as the oxide, carbonate, or sulphate, was not toxic, but that with lead chloride, so soon as .25 per cent. of lead was exceeded, a toxic effect was produced. It was thought well to continue the lead chloride series for a second year. At the same time a fresh series was started, using lead chloride in smaller and intermediate amounts.

i—Old Series.

The quantities of lead used in 1922 were .25 per cent., .50 per cent., and 1 per cent., as chloride. The soil was from Stackyard Field, and the salts were mixed with the whole of the soil

in a pot, each experiment being in duplicate. In 1922, .25 per cent. of lead had produced a crop somewhat in excess of the control, but with .50 per cent. only a few stunted plants were left, and with 1 per cent. everything was killed.

Wheat was sown again in the old pots on December 23rd, 1922, after the soil had been turned out, sieved, and replaced. The plants came up quite well with the .25 per cent. and .50 per cent., but with 1 per cent. only a few weak plants appeared, and these gradually died off. For a time the .25 per cent. and the .50 per cent. looked about as good as the control, but about July, 1923, the .50 per cent. began to show a marked toxic effect. The crops when reaped gave the following comparative results :—

Lead Chloride upon Wheat, 1923. (2nd year).

Treatment	Corn	Straw
Untreated	100	100
Lead Chloride ·25 per cent Lead	79	92
,, ,, ·50 ,, ,, ,, ...	3	37
,, ,, 1·0 ,, ,, ,, ...	—	—

From this it is clear that the toxic influence of 1 per cent. and .50 per cent. of lead used as chloride will continue for a second year, and that even .25 per cent. will show, in a second year, some ill effect. It is true that in the first year .25 per cent. gave some increase of crop, but it has to be remembered that then some of the plants were destroyed, while the rest, as is often the case with pot experiments, developed abnormally. In the form of chloride 0.25 per cent. of lead must, therefore, be considered harmful.

ii—New Series.

The quantities decided on were .20 per cent., .30 per cent., .40 per cent. and .50 per cent. of lead as chloride. The soil now used was from Lansome Field, and the salts were mixed with the whole soil; experiments were, as usual, in duplicate.

The wheat was sown on December 23rd, 1922, and came up well in all the pots, none of the plants being killed off. The .20 per cent. application, and possibly the .30 per cent., seemed to show an improvement on the control, but with the higher amounts there was a gradual diminution. The crops were cut on August 13th, when they gave the following comparative returns :—

Lead Chloride upon Wheat, 1923.

Treatment	Corn	Straw
Untreated	100	100
Lead Chloride ·20 per cent Lead	126	124
,, ,, ·30 ,, ,, ,, ...	129	119
,, ,, ·40 ,, ,, ,, ...	70	83
,, ,, ·50 ,, ,, ,, ...	14	37

The results in general were not as marked as in 1922 when, however, a different soil was used. But the results are in each case in the same direction and tend to show that lead as chloride will be toxic, and almost entirely destroy a crop at a concentration of .50 per cent. It was noticed after removal of the soil from the pots at the close of the experiment that, with the higher concentrations, viz., .50 per cent. and 1 per cent., a deposit of metallic lead formed round the edge of the soil on the inside of the pots.

(*b*) Uranium Compounds.

In 1919, experiments had been made with ores stated to be "radio-active," but no benefit was found from their use. As the activity of these ores was believed to be dependent upon the presence of compounds of uranium, experiments were made with salts of this metal. Wheat was used, and the soil was from Lansome Field. The oxide (as sodium diuranate) and uranyl chloride, sulphate and nitrate were tried, each concentration supplying .05 per cent. and .10 per cent. respectively of uranium. The quantities were mixed with the whole of the soil in each pot, these being filled on December 19th-20th, 1922, and sown with wheat on December 23rd.

Germination was quicker with the untreated pots. The poorest lots were those with the chloride and sulphate. About the end of April the treated pots improved. The absence of sun in May prevented any marked change, except that in some cases —chiefly with the sulphate and chloride—one or two plants developed abnormally. The wheat was cut on August 13th, and the comparative results obtained were :—

Uranium Compounds on Wheat, 1923.

Treatment	Corn	Straw
Untreated	100	100
Sodium diuranate containing Uranium ·05 per cent. ...	95	102
,, ,, ,, ,, ·10 ,, ...	126	120
Uranyl chloride ,, ,, ·05 ,, ...	78	88
,, ,, ,, ,, ·10 ,, ...	74	68
Uranyl sulphate ,, ,, ·05 ,, ...	76	84
,, ,, ,, ,, ·10 ,, ...	6	9
Uranyl nitrate ,, ,, ·05 ,, ...	96	99
,, ,, ,, ,, ·10 ,, ...	100	146

With the doubtful exception of the .1 per cent. dose of sodium diuranate, uranium had no good effect, and in most forms it was actually harmful.

2. *Green-manuring Experiments.*

New interest having been aroused in the subject of green-manuring, it was decided to revert to the experiments at the Woburn Pot-culture Station which had been previously carried on in conjuncion with the Field Experiments, but which had been temporarily suspended.

Briefly to recapitulate, field experiments conducted on Lansome Field since 1895, and on Stackyard Field since 1911, had shown that, without exception, better cereal crops (both of wheat

and of barley) followed the ploughing-in, or the feeding-off, of mustard than of tares, this being contrary to what would be expected from scientific considerations as to the power of tares to utilise atmospheric nitrogen, a power not possessed by the mustard crop.

Whether this unexpected result was due to the particular nature of the soil in question or to considerations of moisture, mechanical condition, etc., was unknown, though one set of experiments conducted at the Pot-culture Station seemed to point to the fact that if the tares were plentifully supplied with water all through the growing period, then they would give the better succeeding cereal crop. Such conditions, however, could not obtain in practice, and the experiments had no further interest beyond showing that the experience of the superiority of tares on a heavy soil, where moisture is better retained, may in this way be accounted for. Repeated analyses of the soils and of the crops grown and ploughed in or fed off had shown more nitrogen to accrue from the growing of tares than of mustard, and yet, for some reason, it could not be utilised for the following corn crop.

1923.

In renewing the enquiry by pot-culture methods, it was now determined to try the addition to the soils of the respective plots (the soil being taken direct from the plots in the fields), of materials such as lime, superphosphate, and sulphate of potash, and to see if these brought about any change.

The quantities so added were :—

Lime	at the rate of	2 tons	per acre.
Superphosphate (30%)	,, ,,	3 cwt.	,,
Sulphate of potash (90%)	,, ,,	1 cwt.	,,

These were used both singly and, in a fourth instance, all of them together. The additions were given to the soils previous to sowing of wheat, they being mixed with the whole of the soil, and wheat was sown on December 23rd, 1923.

In the case of Stackyard Field soil, the green crops had been fed off by sheep in 1922; in that of Lansome Field the green crop had been ploughed in. In each field wheat had been sown in November (1922), so that the crops in the field and at the Pot-culture Station were in the same stage.

(*a*) Stackyard Field Soil.

The plants grew satisfactorily, and up to the middle of February no changes were noticeable. Then, however, the tares series as a whole looked rather better than the mustard. Also the pots in which lime had been used, either alone or in conjunction with the two mineral manures, began to show to advantage, both with tares and with mustard; these differences remained more or less throughout the summer. The influence of superphosphate and of sulphate of potash was hardly apparent.

The weather was very unfavourable in June, and when warmer weather came in July it was almost too late to allow the plants to benefit fully.

It should be noted here that the entire Stackyard Field series was somewhat inferior to the Lansome Field series.

(*b*) LANSOME FIELD SOIL.

Much the same comparative observations as just recorded were made in this series, the crops being, however, as stated, slightly superior to the Stackyard Field soil ones.

After threshing in November, the following comparative results were obtained :—

Green-manuring Experiment—Wheat after green crops, 1923.

	(a) STACKYARD FIELD SOIL		(b) LANSOME FIELD SOIL	
	Corn	Straw	Corn	Straw
i. *Wheat after Tares.*				
Untreated	100	100	100	100
Lime—2 tons per acre	143	166	202	174
Superphosphate—3 cwt. per acre ...	97	96	91	92
Sulphate of Potash—1 cwt. per acre	99	96	83	96
Lime, Superphosphate and S/Potash	153	160	174	177
ii. *Wheat after Mustard.*				
Untreated	100	100	100	100
Lime—2 tons per acre	244	206	327	205
Superphosphate—3 cwt. per acre ...	99	133	125	91
Sulphate of Potash—1 cwt. per acre	101	117	128	103
Lime, Superphosphate and S/Potash	233	191	275	179

These results are most consistent and point clearly to the benefit resulting from the use of lime. This is the case with both soils and with both green crops. Superphosphate and sulphate of potash, on the other hand, produced no benefit in either, and the advantage obtained in the mixed dressing was clearly due to the lime.

Taking the actual crop returns and not those stated in the Table (given in percentages of the untreated produce), there was no very marked difference between the tares soil and the mustard soil. The actual weights for the untreated and limed pots were :—

	STACKYARD FIELD SOIL		LANSOME FIELD SOIL	
	Corn	Straw	Corn	Straw
i. *Wheat after Tares.*	grammes	grammes	grammes	grammes
Untreated	13·9	20·3	11·8	18.6
Limed	19·9	33·3	23·8	32·4
ii. *Wheat after Mustard.*				
Untreated	8·3	14·0	8.3	17·7
Limed	20·3	28·7	27·2	36·1

In pot-culture work, too much importance must not be attached to actual crop-weighings, and the above results must be taken purely as an indication, but a very clear one, as to the benefit likely to accrue from liming both lands and both sets of plots. Whether doing this will result in bringing out in practice differences between the two green crops, remains to be seen; but. acting upon the above results, it was determined to lime one half of each of the plots in Stackyard Field and Lansome Field in the winter of 1923, lime being put on at the rate of 2 tons per acre, the other halves being left unlimed.

1924.

The experiment was carried on for a second year, the green crops, tares and mustard, being grown, but no further manurial applications given. The green crops were sown on March 26th, and were cut June 23rd, the weights, both green and dry, being recorded. There is no occasion for dealing with these in detail, but it may be said generally that the differences were not marked; what indications of increased crop were given bore, as with the wheat of 1923, on the result of applying lime or a complete manure including lime.

3. *The Relative Values of Lime and Chalk.*

1923.

In previous experiments on this subject the soil had not had any applications given it beyond the lime and chalk respectively. The experiment was therefore repeated, with the addition of superphosphate and sulphate of potash, at the rates of 3 cwt. and 1 cwt. per acre respectively. The soil used came, not from Stackyard Field as usual, but from Lansome Field. The 40-lb. pots were filled with soil, the whole of which was previously mixed with lime or with chalk, so as to give the equivalent of 10 cwt., 1 ton, 2 tons, 3 tons and 4 tons of lime per acre. The superphosphate and sulphate of potash were added to the top 16 lb. of soil used, wheat being sown on December 23rd.

All the plants came up well. About the middle of March, both lime, and to a lesser extent chalk, showed a clear improvement over the control (unlimed) pots. In the case of the lime applications the improvement was greater with the heavier dressings. This held good until July, when the lime series showed a progressive increase of crop up to 3 tons, but with 4 tons the crop was shorter, though individual plants were greener and stronger. With chalk, however, though there was a general increase over the control, the heavier applications were not better than the 10 cwt. per acre. The crop was cut on August 13th, and the following comparative results were obtained :—

Lime and Chalk upon Wheat—Lansome Field Soil, 1923.

Treatment	Corn	Straw
No Lime	100	100
Lime (CaO) 10 cwt. per acre	129	125
,, ,, 1 ton ,, ,, ...	140	145
,, ,, 2 tons ,, ,, ...	191	183
,, ,, 3 ,, ,, ,, ...	228	225
,, ,, 4 ,, ,, ,, ...	207	254
Chalk = 10 cwt. CaO ,, ,, ...	137	128
,, = 1 ton ,, ,, ,, ...	126	135
,, = 2 tons ,, ,, ,, ...	139	132
,, = 3 ,, ,, ,, ,, ...	141	129
,, = 4 ,, ,, ,, ,, ...	157	141

The weights are in close accordance with the appearances already discussed, and with previous experiments made with the

soil of Stackyard Field, and show that the gains already recorded do not depend upon the presence or absence of phosphates and potash, but are the direct result of the applications of lime and chalk respectively.

1924.

A return was made in 1924 to Stackyard Field soil, phosphates and potash being used additionally as in 1923. The same amounts of lime and chalk were used as in 1923, and mixed, as then, with the top six inches of soil. An addition of ground limestone, at the rate of 1 ton and 2 tons per acre respectively, was, however, made this year. Wheat was sown on December 18th, 1923. It was noticed that the higher amounts of chalk retarded the germination, but eventually all plants came well. By April the lime pots showed an increasing improvement up to 3 tons per acre, a slight drop occurring with 4 tons. The chalk pots, on the other hand, were not so good, but more level, while limestone showed no increase.

These appearances were maintained more or less to the end of the growing period, and the crops were cut on August 18th. The recorded comparative results were :—

Lime and Chalk upon Wheat—Stackyard Field Soil, 1924.

Treatment	Corn	Straw
No Lime	100	100
Lime (CaO) 10 cwt. per acre	113	100
,, ,, 1 ton ,, ,, ...	136	133
,, ,, 2 tons ,, ,, ...	145	167
,, ,, 3 ,, ,, ,, ...	168	196
,, ,, 4 ,, ,, ,, ...	179	194
Chalk = 10 cwt. CaO ,, ,, ...	94	88
,, = 1 ton ,, ,, ,, ...	94	79
,, = 2 tons ,, ,, ,, ...	101	94
,, = 3 ,, ,, ,, ,, ...	99	93
,, = 4 ,, ,, ,, ,, ...	92	78
Ground Limestone 1 ton per acre	84	72
,, ,, 2 tons ,, ,, ...	85	76

The results again confirm the preceding ones, and also indicate that limestone is ineffectual in the first year.

4. *Magnesia and Magnesium Carbonate on Wheat,* 1924.

As a counterpart of the last-named experiment, a repetition of earlier experiments with magnesia and magnesium carbonate on Stackyard Field soil was made in 1924, phosphates and potash being given also, magnesium limestone also being added to the series. The applications were mixed, as before, with the top six inches of soil, and the respective quantities used were the same as in the lime and chalk experiment (3). Wheat was sown on December 18th, 1923.

From the beginning, magnesia in the higher amount exercised a bad effect upon the young plants, this not being apparent

with magnesium carbonate. By the end of May, 1924, all the plants in the 2, 3 and 4 tons per acre of magnesia lots were killed. One ton per acre showed some ill effect at first, but the crop recovered. With magnesium carbonate there was no failure, but, on the contrary, a slight proportional increase all round.

The crops were cut on August 18th, and the comparative results were :—

Magnesia and Magnesium Carbonate upon Wheat—Stackyard Field Soil, 1924.

Treatment	Corn	Straw
No Magnesia	100	100
Magnesia (MgO) 10 cwt. per acre	185	189
,, ,, 1 ton ,, ...	180	216
,, ,, 2 tons ,, ...	—	—
,, ,, 3 ,, ,, ...	—	—
,, ,, 4 ,, ,, ...	—	—
Magnesium Carbonate = 10 cwt. MgO per acre	148	158
,, ,, ,, = 1 ton	191	199
,, ,, ,, = 2 tons	201	230
,, ,, ,, = 3 ,, ...	226	240
,, ,, ,, = 4 ,, ...	191	235
Ground Magnesian Limestone = 1 ton per acre	108	108
,, ,, ,, 2 tons	108	108

The Table shows that an increase of crop is given with a half-ton and 1 ton of magnesia, but that 2 tons per acre or more will absolutely kill a wheat crop, whereas higher amounts of magnesia as carbonate will improve the crop. Magnesian limestone, however, is ineffective, at least in the first year.

These experiments on lime and magnesia (3 and 4), confirmed, as they have been, on different soils of the farm, and with and without mineral manures, leave no doubt that there is a very marked difference between the effect of caustic lime and that of carbonate of lime, and again, between lime and magnesia. Caustic lime has clearly been proved to be a far more active form than chalk, and, while its addition, within reason—say up to 2 and 3 tons per acre—will produce much benefit on land requiring lime, magnesia, in the caustic state, will in that amount prevent the growth of the crop. The further information is now given that ground limestone, be it magnesian or not, exercises no influence, for a time at least.

These experiments have now been, in the main, so frequently repeated, and with like general results, as to leave practically no room for doubt as to their bearing on agricultural practice, and on the respective use of caustic lime, chalk, caustic magnesia or carbonate of magnesia. Incidentally, as I have pointed out elsewhere, they have a marked bearing on the practical treatment of land which contains magnesia in excess of the lime present.

5. *Sulphate of Ammonia and Muriate of Ammonia Compared.*

Along with the field experiment on this subject (see page 86) a similar one was carried out at the Pot-culture Station. The soil was from the headland of Stackyard Field, the crop, wheat. A dressing of superphosphate and sulphate of potash was given to each lot at sowing time, and the ammonia salts were given later as top-dressings. These latter consisted of sulphate of ammonia, 1 cwt. per acre, and muriate of ammonia equivalent in ammonia to 1 cwt. per acre of sulphate of ammonia.

Wheat was sown on December 23rd, 1922; the top-dressings were given on June 11th. Towards the end of July the muriate pots looked the better, though the ripening of the crops was retarded.

The crops were cut on August 14th and gave the following comparative returns :—

Sulphate of Ammonia and Muriate of Ammonia, 1923.

Applications per acre	Corn	Straw
Superphosphate 3 cwt. + S/Potash 1 cwt.	100	100
Superphosphate 3 cwt. + S/Potash 1 cwt. + S/Amm. 1 cwt.	145	131
Superphosphate 3 cwt. + S/Potash 1 cwt. + M/Amm. = 1 cwt. of S/Amm.	171	138

The results were confirmatory of the field ones, and indicated the superiority of the muriate in the case, at least, of corn crops.

ERRATA

Page 100. Harvest 1924, line 5, for 28 tons read 8 tons.

Page 102. Conversion Table, line 2, for 0.346 Hectolitre (36.346 litres) read 0.364 Hectolitre (36.364 litres).

Page 114. Malting Barley, 1923, line 4, column 5, for 1265 read 1625.

Page 122. Clover, 1924, in last six columns for cwt. read lb.

DATES OF SOWING AND HARVESTING (Harvest 1923).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	*Carting began.	*Carting finished.	Yield per Acre.
Great Knott, east ...	Fallow	... ...	... ...	... ...	... ...	... ...	... ...	... ...
,, west ...	Wheat	Red Standard	Oct. 27, '22	Oct. 30, '22	Aug. 10	Aug. 22	Sept. 3	37·5 bush.
Little Knott	Potatoes	Kerr's Pink	May 11, '23	May 17, '23	... ...	Oct. 29	Oct. 29	see p.118
Foster's, east	Mangolds* ...	Prizewinner Yellow Globe ...	May 2, '23	May 10, '23	... ...	frosted		... ...
,, west	Swedes	Hurst's Monarch	May 15, '23	May 23, '23	... ...	Oct. 20	Nov. 8	14·3 tons.
West Barnfield	Oats	Grey Winters ... ... White Winters	Oct. 12, '22	Oct. 13, '22	Aug. 2	Aug. 13	Aug. 14	48·0 bush.
Long Hoos, east ...	Barley	Plumage Archer	Apr. 18, '23	Apr. 18, '23	Aug. 16	Sept. 3	Sept. 6	32·0 bush.
,, west ...	Clover	Red	May 10, '22	May 10, '22	July 2	July 13	July 14	
New Zealand	Clover	Red	May 2, '22	May 4, '22	June 25	July 3	July 18	1·4 tons.
Stackyard	Clover	Red	May 5, '22	May 16, '22	June 29	July 9	July 19	
Great Harpenden ...	Wheat	Red Standard	Nov. 16, '22	Nov. 30, '22	Aug. 13	Aug. 22	Aug. 29	24·0 bush.
Sawpit	Oats	Black Winters ... ... Grey Winters	Oct. 10, '22	Oct. 12, '22	July 27	Aug. 10	Aug. 11	42·5 bush.
Sawyers	Barley	Plumage Archer	Apr. 18, '23	Apr. 19, '23	Aug. 21	Sept. 6	Sept. 7	40·0 bush.
	Potatoes ...	Kerr's Pink	May 4, '23	May 5, '23	... ...	Nov. 1	Nov. 17	see p.121
	Fallow	... ...	... ...	... ...	... ...	... ...	... ...	... ...
Broadbalk	Wheat	Red Standard	Oct. 31, '22	Nov. 1, '22	Aug. 15	Aug. 27	Aug. 28	see p.108
Little Hoos	Clover	Red ... ... 1st Crop	May 8, '22	May 9, '22	June 28	July 6	July 7	,, 112
		2nd Crop	... ...	... ...	Aug. 25	Sept. 5	Sept. 5	,, 112
Hoos	Barley	Plumage Archer	Apr. 20, '23	Apr. 20, '23	Aug. 22	Sept. 3	Sept. 6	,, 110
Barnfield	Mangolds ...	Prizewinner Yellow Globe ...	Apr. 30, '23	Apr. 30, '23	... ...	Nov. 17	Dec. 15	,, 103
Agdell	Wheat	Red Standard	Oct. 30, '22	Oct. 30, '22	Aug. 9	Aug. 17	Aug. 18	,, 102
Great Field	Grass	... ...	... ...	... ...	July 17	July 21	July 23	,, 124
Park	Grass	... 1st Crop	... ...	... ...	June 16	June 22	June 23	,, 104
		2nd Crop	... ...	... ...	Dec. 20	Jan.15'24	Jan.17'24	,, 104

* In the case of roots, the dates given are those on which lifting began and finished.

DATES OF SOWING AND HARVESTING (Harvest 1924).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	*Carting began.	*Carting finished.	†Yield per Acre.
Great Knott, east ...	Oats	Black Winter	Oct. 16, '23	Oct. 17, '23	Aug. 5	Aug. 23	Aug. 25	16 bush.
,, west ...	Oats	Grey Winter	Nov. 5, '23	Nov. 7, '23	Aug. 8	Aug. 25	Aug. 27	14 ,,
Little Knott	Barley	Plumage Archer	Mar. 14, '24	Mar. 17, '24	Aug. 20	Sept. 8	Oct. 17	28 ,,
Foster's, east	Swedes	Hurst's Monarch	May 28, '24	May 30, '24	... ...	Nov. 5	Nov. 28	25 tons
,, west	Potatoes ...	Kerr's Pink	May 6, '24	May 10, '24	... ...	Oct. 1	Nov. 4	28 ,,
	Mangolds ...	Prizewinner Yellow Globe ...	May 27, '24	May 28, '24	... ...	Nov. 17	Nov. 21	27 ,,
West Barnfield	Wheat	Red Standard	Nov. 1, '23	Nov. 3, '23	Sept. 4	Sept. 19	Sept. 22	24 bush.
Long Hoos, east ...	Clover	Broad Red	Apr. 18, '23	Apr. 19, '23	June 23	July 2	July 4	2.5 tons
,, west ...	Wheat	Red Standard	Oct. 19, '23	Oct. 20, '23	Aug. 22	Sept. 3	Sept. 5	28 bush.
Great Harpenden ...	Barley	Plumage Archer	Mar. 18, '24	Mar. 21, '24	Aug. 15	Aug. 28	Oct. 15	26 ,,
New Zealand	Wheat	Red Standard	Nov. 19, '23	Nov. 21, '23	Sept. 3	Sept. 18	Oct. 10	25 ,,
Stackyard	Wheat	Red Standard	Nov. 12, '23	Nov. 15, '23	Sept. 2	Sept. 16	Oct. 10	20 ,,
Sawpit	Barley	Plumage Archer	Apr. 4, '24	Apr. 5, '24	Sept. 1	Sept. 19	Oct. 7	26 ,,
Sawyers	Clover	Broad Red	Apr. 24, '23	Apr. 24, '23	June 24	July 5	July 8	1.5 tons
	Barley	Plumage Archer	Mar. 31, '24	Mar. 31, '24	Sept. 1	Sept. 24	Sept. 24	20 bush.
Broadbalk	Wheat	Red Standard	Nov. 9, '23	Nov. 12, '23	Sept. 5	Sept. 25	Oct. 3	see p. 109
Little Hoos	Wheat	Red Standard	Nov. 21, '23	Nov. 22, '23	Sept. 3	Sept. 22	Sept. 24	,, 112
Hoos	Barley	Plumage Archer	Mar. 17, '24	Mar. 18, '24	Aug. 26	Oct. 3	Oct. 10	,, 110
Barnfield	Mangolds ...	Prizewinner Yellow Globe ...	Apr. 25, '24	Apr. 25, '24	... ...	Oct. 27	Nov. 17	,, 103
Agdell	Turnips	Aberdeen Yellow	July 19, '24	July 19, '24	... ...	Nov. 28	Dec. 5	,, 102
Great Field	Hay	... ...	... ...	... ...	June 26	June 30	June 30	,, 124
Park	Grass	1st crop	... ...	... ...	June 24	June 27	June 28	,, 104

* In the case of roots, the dates given are those on which lifting began and finished. † Estimates of standing crops.

METEOROLOGICAL RECORDS, 1923 and 1924.

	Rain.		Drainage through soil.				Temperature (Mean).				
	Total Fall. $\frac{1}{1000}$ Acre Gauge.	No. of Rainy Days. (0·01 inch or more) $\frac{1}{1000}$ Acre Gauge.	20 ins. deep.	40 ins. deep.	60 ins. deep.	Bright Sun-shine.	Max.	Min.	1 ft. in ground.	Solar Max.	Grass Min.
1923	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.	°F.	°F.	°F.
Jan. ...	1·500	12	1·269	1·449	1·296	59·8	46·1	34·7	38·4	70·0	29·2
Feb. ...	3·914	23	3·510	3·598	3·346	53·5	46·0	36·8	40·6	77·7	32·4
Mar. ...	2·481	16	1·584	1·754	1·620	75·9	48·4	36·7	41·3	86·9	31·6
April ...	1·480	12	0·371	0·434	0·401	115·3	52·3	38·0	45·1	103·9	32·4
May ...	1·681	14	0·177	0·180	0·179	166·2	56·7	42·0	50·4	115·8	37·8
June ...	0·617	9	0·003	0·045	0·047	116·1	60·7	46·8	53·6	111·3	42·2
July ...	3·871	12	1·380	1·395	1·355	223·8	72·5	55·1	63·1	127·3	50·2
Aug. ...	2·329	11	0·342	0·375	0·295	256·9	68·5	51·1	60·7	124·1	44·8
Sept. ..	2·541	12	1·009	1·023	0·891	189·1	62·9	46·1	54·4	114·1	39·2
Oct. ...	4·974	23	3·691	3·691	3·452	98·3	55·4	43·9	50·0	96·1	39·0
Nov. ...	1·648	14	1·083	1·147	1·068	103·9	42·2	31·0	40·4	77·6	26·3
Dec. ...	2·932	19	2·630	2·592	2·467	42·3	42·6	31·4	37·0	60·5	28·1
Total or Mean	29·968	177	17·049	17·683	16·417	1501·1	54·5	41·1	47·9	97·1	36·1
1924											
Jan. ...	2·898	19	3·024	3·199	3·196	58·1	43·5	34·8	38·1	64·1	31·2
Feb. ...	0·714	12	0·045	0·097	0·087	54·8	40·2	31·5	36·9	67·3	28·4
Mar. ...	1·138	10	0·379	0·390	0·364	174·2	47·1	31·3	37·1	92·4	25·0
April ...	3·182	14	1·358	1·324	1·281	157·5	52·4	37·2	42·6	102·4	31·3
May ...	4·628	21	2·208	2·228	2·201	190·9	61·0	45·3	52·2	117·9	41·9
June ...	1·974	11	0·666	0·823	0·733	199·6	65·2	50·2	59·3	126·1	46·2
July ...	4·533	16	1·763	1·801	1·670	236·1	68·3	51·0	61·1	127·6	45·3
Aug. ...	2·551	22	0·080	0·095	0·056	169·0	64·8	50·5	58·7	121·6	46·6
Sept. ...	3·417	19	1·312	1·265	1·105	118·4	61·4	50·8	56·6	110·9	46·7
Oct. ...	4·279	21	3·549	3·494	3·333	89·9	55·3	45·3	51·3	89·9	40·3
Nov. ...	3·271	12	2·749	2·789	2·651	36·1	48·1	39·6	45·2	70·4	35·9
Dec. ...	3·920	20	3·637	3·742	3·638	42·5	46·4	37·8	42·7	63·3	34·2
Total or Mean	36·505	197	20·770	21·247	20·315	1527·1	54·5	42·1	48·5	96·2	37·8

RAIN AND DRAINAGE.
MONTHLY MEAN FOR 54 HARVEST YEARS, 1870-1—1923-4.

	Rainfall.	Drainage.			Drainage % of Rainfall.			Evaporation.		
		20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge
	Ins.	Ins.	Ins.	Ins.				Ins.	Ins.	Ins.
September	2·348	0·762	0·727	0·666	32·5	31·0	28·4	1·586	1·621	1·682
October ...	3·143	1·793	1·749	1·624	57·0	55·6	51·7	1·350	1·394	1·519
November	2·724	2·053	2·086	1·965	75·4	76·6	72·1	0·671	0·638	0·759
December	2·851	2·426	2·511	2·397	85·1	88·1	84·1	0·425	0·340	0·454
January ...	2·374	1·922	2·104	2·024	81·0	88·6	85·3	0·452	0·270	0·350
February	1·995	1·468	1·569	1·496	73·6	78·6	75·0	0·527	0·426	0·499
March ...	2·076	1·125	1·257	1·188	54·2	60·5	57·2	0·951	0·819	0·888
April ...	2·043	0·666	0·736	0·703	32·6	36·0	34·4	1·377	1·307	1·340
May ...	2·048	0·488	0·548	0·515	23·8	26·8	25·2	1·560	1·500	1·533
June ...	2·270	0·564	0·586	0·565	24·8	25·8	24·9	1·706	1·684	1·705
July ...	2·713	0·718	0·743	0·691	26·5	27·4	25·5	1·995	1·970	2·022
August ...	2·683	0·706	0·707	0·664	26·3	26·4	24·7	1·977	1·976	2·019
Year ...	29·268	14·691	15·323	14·498	50·2	52·4	49·5	14·577	13·945	14·770

Area of each gauge $\frac{1}{1000}$th acre.

CROP YIELDS ON THE EXPERIMENTAL PLOTS.

NOTES.—In each case the year refers to the harvest, *e.g.*, Wheat harvested in 1924. In the tables, total straw includes straw, cavings and chaff.

CONVERSION TABLE.

1 acre ... ... =	0·404 Hectare	0·963 Feddan.
1 bushel (Imperial) =	0·346 Hectolitre (36·346 litres) ...	0·184 Ardeb.
1 lb. (pound avoirdupois) =	0·453 Kilogramme	1·009 Rotls.
1 cwt. (hundredweight) =	50·8 Kilogrammes	113·0 Rotls. 1·366 Maunds.
1 metric quintal ... =	100·0 Kilogrammes ... ... 220·46 lb.	
1 bushel per acre ... =	0·9 Hectolitre per Hectare ...	0·191 Ardeb per Feddan.
1 lb. per acre ... =	1·12 Kilogramme per Hectare ...	1·049 Rotls per Feddan.
1 cwt. per acre ... =	125·60 Kilogrammes per Hectare or 1·256 metric Quintals per Hectare	117·4 Rotls per Feddan.

In America the Winchester bushel is used = 35·236 litres. 1 English bushel = 1·032 American bushels.

CROPS GROWN IN ROTATION. AGDELL FIELD.

PRODUCE PER ACRE.

Year.	CROP.	O. Unmanured.		M. Mineral Manure.		C. Complete Mineral and Nitrogenous Manure.	
		5. Fallow.	6. Clover or Beans.	3. Fallow.	4. Clover or Beans.	1. Fallow.	2. Clover or Beans.
	AVERAGE OF THE FIRST NINETEEN COURSES, 1848-1923.						
	Roots (Swedes) cwt.*	32·7	11·2	175·7	195·9	355·3	302·0
	Barley—						
	Dressed Grain bush.	22·7	20·9	23·8	27·9	32·2	36·8
	Total Straw ... cwt.	13·9	13·7	14·0	16·0	19·5	22·6
	Beans—						
	Dressed Grain bush.	—	13·1	—	18·2	—	22·3
	Total Straw ... cwt.	—	9·2	—	13·2	—	15·3
	Clover Hay ... cwt.	—	28·3	—	54·1	—	55·0
	Wheat—						
	Dressed Grain bush.	24·2	22·8	28·5	31·2	29·5	31·2
	Total Straw ... cwt.	23·7	21·7	29·0	30·3	31·4	30·4
	NINETEENTH COURSE, 1920-23.						
1920	Roots (Swedes) ... cwt.	20·5	2·1	163·9	270·0	262·1	56·4‡
1921	Barley—						
	Dressed Grain bush.	13·0	2·4†	12·8	26·3	10·9	25·7
	Offal Grain ... lb.	57·0	42·0	45·0	58·0	39·0	65·0
	Straw ... ... lb.	891·0	601·0	596·0	1124·0	444·0	1444·0
	Total Straw ... cwt.	10·9	7·8	7·9	14·2	6·3	17·7
	Wt. of Dressed Grain per bush. lb.	55·1	51·0	56·5	56·8	56·4	56·7
	Proportion of Total Grain to 100 of Total Straw	63·0	19·0	86·3	97·5	92·2	77·1
1922	Clover Hay ... cwt. (1 crop only)	—	4·4	—	9·7	—	3·5
1923	Wheat—						
	Dressed Grain bush.	18·0	25·2	20·3	28·3	19·7	22·9
	Offal Grain ... lb.	174·0	206·0	190·0	221·0	205·0	220·0
	Straw ... ... lb.	2019·0	2575·0	2590·0	2975·0	2363·0	2390·0
	Total Straw ... cwt	20·6	26·5	26·9	30·7	24·3	24·5
	Wt. of Dressed Grain per bush lb.	63·6	63·4	63·5	64·3	64·3	64·6
	Proportion of Total Grain to 100 of Total Straw	57·0	60·7	49·0	59·4	54·0	61·9
	PRESENT COURSE (20th), 1924.						
1924	Roots (Turnips) ... cwt.	2·9	0·7	42·8	31·5	127·4	104·7

* Plots 1, 3 and 5 based upon 18 years. Plots 2, 4 and 6 based upon 17 years.
† Plot 6 was more badly attacked by Gout Fly than the other plots.
‡ The roots on this plot were badly attacked by finger and toe disease in 1920. In 1920 Rape Cake was omitted from plots 1 and 2.

MANGOLDS, BARN FIELD, 1923 and 1924.

Roots since 1856. Mangolds since 1876.

Produce per Acre.

Strip.	Strip Manures.	Cross Dressings.				
		O.	N.	A.	A.C.	C.
		None.	Nitrate of Soda	Ammon. Salts.	Ammon. Salts and Rape Cake.	Rape Cake.
	1923†.	Tons.	Tons.	Tons.	Tons.	Tons.
1	Dung only	R. **16·55**	**32·69**	**23·67**	**21·63**	**22·29**
		L. 2·20	3·70	3·78	4·15	4·18
2	Dung, Super., Potash ...	R. **18·92**	**37·38**	**30·40**	**29·64**	**29·96**
		L. 2·16	4·48	4·64	5·23	4·11
4	Complete Minerals ...	R. **4·72**	*a* R. **22·04***	**19·18**	**25·28**	**20·85**
			a L. 3·69			
		L. 0·92	*b* R. **19·18**	2·82	5·12	2·96
			b L. 3·70			
5	Superphosphate only ...	R. **5·22**	**19·09**	**8·48**	**6·16**	**6·59**
		L. 1·23	2·92	3·54	3·15	3·21
6	Super. and Potash ...	R. **4·25**	**19·73**	**16·08**	**18·39**	**16·48**
		L. 1·06	2·56	2·65	4·50	2·72
7	Super., Sulphate of Mag., and Sodium Chloride	R. **4·71**	**21·92**	**19·82**	**17·53**	**15·44**
		L. 1·11	2·86	2·78	4·62	2·69
8	None	R. **3·63**	**11·05**	**5·90**	**4·71**	**3·47**
		L. 1·14	2·72	2·80	2·49	1·92
9	Sodium Chloride, Nit. Soda, Sulph. Potash, and Sulph. Mag. ...	R. **24·73**	—	—	—	—
		L. 3·03				
	1924.					
1	Dung only	R. **14·49**	**23·99**	**20·75**	**28·38**	**24·80**
		L. 3·83	6·11	6·43	6·77	5·29
2	Dung, Super., Potash ...	R. **18·61**	**25·08**	**23·28**	**34·17**	**32·15**
		L. 3·86	5·68	5·52	7·20	6·13
4	Complete Minerals ...	R. **3·15**	*a* R. **14·34**	**14·42**	**34·16**	**20·91**
			a L. 4·55			
		L. 1·06	*b* R. **11·15**	3·50	5·62	3·66
			b L. 4·19			
5	Superphosphate only ...	R. **3·31**	**14·92**	**11·47**	**15·81**	**15·31**
		L. 1·03	3·76	3·61	4·83	3·54
6	Super. and Potash ...	R. **3·16**	**12·58**	**16·40**	**29·40**	**20·55**
		L. 1·12	3·52	2·96	5·73	2·73
7	Super., Sulphate of Mag., and Sodium Chloride	R. **3·42**	**17·28**	**18·34**	**28·91**	**20·18**
		L. 1·11	3·94	3·29	5·24	3·05
8	None	R. **2·14**	**11·70**	**10·18**	**13·35**	**11·55**
		L. 1·87	3·62	3·18	4·32	3·49
9	Sodium Chloride, Nit. Soda, Sulph. Potash and Sulph. Mag. ...	R. **20·46**	—	—	—	—
		L. 3·51				

R. = roots. L. = leaves.

* From 1904 onwards plot 4 N has been divided, 4*a* receiving Sulphate of Potash, Sulphate of Magnesia, Sodium Chloride and Nitrate of Soda; 4*b* receiving Calcium Chloride, Potassium Nitrate and Calcium Nitrate.

† In 1923 plot 4 in series A, N, AC and C were lifted on Nov. 22nd in good condition. The remainder of the plots were lifted Dec. 10th—15th after several severe frosts.

HAY. THE PARK GRASS PLOTS. 1923, 1924.

Plot	Manuring per acre.		1923. Yield of Hay per acre. 1st Crop.	1923. Yield of Hay per acre. 2nd Crop.	1923. Yield of Hay per acre. Total.	1923. Dry Matter per acre. 1st Crop.	1923. Dry Matter per acre. 2nd Crop.	1923. Dry Matter per acre. Total.	1924. Yield of Hay per acre.	1924. Dry Matter per acre.	Plot.
			cwt.	cwt.	cwt.	lb.	lb.	lb.	cwt.	lb.	
1	Single dressing Amm. Salts (=43 lb. N.); (with Dung also 8 years 1856-63)	not limed	23·8	16·2	40·0	1917	310	2227	29·0	2667	1
		limed ...	21·1	9·8	30·9	1732	199	1931	28·1	2551	
2	Unmanured; (after Dung 8 years, 1856-63)	not limed	17·4	6·1	23·5	1297	102	1399	18·1	1518	2
		limed ...	18·0	2·6	20·6	1426	48	1474	23·8	1804	
3	Unmanured	not limed	15·0	5·7	20·7	1165	98	1263	15·8	1383	3
		limed ...	14·9	2·9	17·8	1142	66	1208	17·6	1445	
4-1	Superphosphate of Lime	not limed	20·8	4·4	25·2	1435	83	1518	23·0	1944	4-1
		limed ...	18·7	4·1	22·8	1444	83	1527	20·9	1818	
4-2	Superphosphate of Lime and double dressing Amm. Salts (=86 lb. N.)	not limed	45·5	4·8	50·3	3210	77	3287	27·7	2478	4-2
		limed ...	38·9	21·3	60·2	3135	358	3493	46·4	4319	
5-1	(N. half) Unmanured; following double dressing Amm. Salts (= 86 lb. N.) 1856-97	not limed	20·3	9·9	30·2	1405	191	1596	15·2	1390	5-1
5-2	(S. half) Super., Sulphate of Potash; following double dressing Amm. Salts (= 86 lb. N.) 1856-97	not limed	21·3	20·4	41·7	1593	438	2031	27·3	2287	5-2
6	Complete Mineral Manure as plot 7; following double dressing Amm. Salts (= 86 lb. N.) 1856-68	not limed	23·0	27·3	50·3	1838	507	2345	36·0	3166	6
7	Complete Mineral Manure	not limed	23·0	20·8	43·8	1806	402	2208	36·1	3123	7
		limed ...	38·3	21·3	59·6	2838	438	3276	54·0	4851	
8	Mineral Manure without Potash	not limed	21·3	8·7	30·0	1505	151	1656	21·3	1854	8
		limed ...	19·1	8·7	27·8	1513	200	1713	17·4	1539	
9	Complete Mineral Manure and double dressing Amm. Salts (= 86 lb. N.)	not limed	57·5	17·3	74·8	4009	287	4296	32·9	2946	9
		limed ...	59·9	22·7	82·6	4488	443	4931	66·2	5600	
10	Mineral Manure (without Potash) and double dressing Amm. Salts (= 86 lb. N.)	not limed	45·2	8·3	53·5	3210	132	3342	31·5	2970	10
		limed ...	46·7	28·9	75·6	3197	577	3774	49·1	4744	
11-1	Complete Mineral Manure and treble dressing Amm. Salts (=129 lb. N.)	not limed	72·0	55·5	127·5	4559	779	5338	39·9	3267	11-1
		limed ...	75·8	34·0	109·8	5184	586	5770	73·4	6467	
11-2	As plot 11-1 and Silicate of Soda	not limed	77·4	55·0	132·4	5472	831	6303	50·5	4502	11-2
		limed ...	75·7	33·7	109·4	5219	666	5885	70·8	5957	

12	Unmanured	not limed	19·8	6·0	25·8	1415	147	1562	16·7	1403	12
13	Dung in 1905, and every fourth year since (omitted in 1917). Fish Guano in 1907 and every fourth year since	not limed	60·6	29·2	89·8	4015	535	4550	41·2	3668	13
		limed ...	47·5	29·0	76·5	3264	540	3804	38·1	3392	
14	Complete Mineral Manure and double dressing Nitrate of Soda (=86 lb. N.)	not limed	53·2	26·6	79·8	4298	493	4791	63·7	5142	14
		limed	45·9	17·5	63·4	3400	375	3775	57·4	4854	
15	Complete Mineral Manure as plot 7; following double dressing* Nitrate of Soda (= 86 lb. N.)	not limed	28·5	10·6	39·1	2443	203	2646	45·4	3615	15
		limed ...	24·4	10·2	34·6	2091	221	2312	42·7	3539	
16	Complete Mineral Manure and single dressing Nitrate of Soda (= 43 lb. N.)	not limed	41·5	8·1	49·6	3150	142	3292	47·2	3820	16
		limed ...	42·5	16·9	59·4	3303	345	3648	52·2	4376	
17	Single dressing Nitrate of Soda (= 43 lb. N.)	not limed	31·6	5·8	37·4	1979	105	2084	33·0	2498	17
		limed ...	30·3	6·4	36·7	2293	119	2412	33·7	2769	
18	Potash, Sulphate of Soda, Magnesia and double dressing Sulphate of Amm. (= 86 lb. N.) 1905 and since; following Minerals and Amm. Salts, supplying the constituents of 1 ton of Hay, 1865-1904	not limed	38·3	26·3	64·6	2550	589	3139	28·0	2600	18
		limed (6788 lb.)	48·1	9·0	57·1	3541	231	3772	29·5	2547	
		limed (3951 lb.)	40·0	11·8	51·8	2953	283	3236	32·5	2688	
19	Farmyard Dung in 1905 and every 4th year since (omitted in 1917); following Nitrate of Soda (= 43 lb. N.) and Minerals, 1872-1904	not limed	25·3	27·4	52·7	1943	525	2468	25·3	2392	19
		limed (3150 lb.)	21·6	31·1	52·7	1842	775	2617	27·4	2717	
		limed (570 lb.)	19·1	27·0	46·1	1621	653	2274	24·2	2411	
20	Farmyard Dung in 1905 and every 4th year since (omitted 1917); each intervening year, plot 20 receives Sulphate of Potash, Superphosphate and Nitrate of Soda (=26 lb. N.); following Nitrate of Potash and Superphosphate, 1872-1904	not limed	35·6	28·3	63·9	2857	625	3482	31·7	2984	20
		limed (2772 lb.)	36·2	26·1	62·3	2814	558	3372	35·8	3347	
		limed (570 lb.)	42·6	19·1	61·7	3192	429	3621	51·0	4790	

Ground lime was applied to the Southern portion (limed) of the plots at the rate of 2,000 lb. to the acre in the Winter of 1903-4, 1907-8, 1915-16, 1923-24, and at the rate of 2,500 lb. to the acre in the Winter of 1920-21, except where otherwise stated.

Up to 1914 the limed and unlimed plot results were not separately given in the Annual Report, but the mean of the two was given. From 1915 onwards the separate figures are given.

The 2nd Hay Crop, 1923, was carted in very bad condition as the plots could only be cut when the frost was on them. The Dry Matter figures give a truer indication of the relative yields of the different plots.

The Park Grass Plots.

BOTANICAL COMPOSITION, PER CENT. 1921, 1st Crop.

Plot.	Manuring.	Liming.	Gramineæ.	Leguminosæ.	Other Orders.	"Other Orders" consist largely of	Plot.
3	Unmanured	Limed ...	68·4	10·5	21·1	Plantago lanceolata	3
		Not limed	73·1	4·7	22·2	Plantago lanceolata	
5-1	Unmanured, following double Amm. Salts, 1856-97	Not limed	86·8	1·1	12·1	Centaurea nigra	5-1
5-2	Super. and Sulph. Potash following double Amm. Salts, 1856-97 ...	Not limed	72·5	9·2	18·3	Rumex acetosa	5-2
7	Complete Mineral Manure	Limed ...	66·1	22·0	11·9	Heracleum sphondylium	7
		Not limed	68·9	13·5	17·6	Achillea millefolium	
9	Complete Mineral Manure and double Amm. Salts	Limed ...	96·3	—	3·7	Rumex acetosa; Heracleum sphondylium	9
		Not limed	99·0	—	1·0	Rumex acetosa	
14	Complete Mineral Manure and double Nitrate of Soda	Limed ...	95·5	3·0	1·5	Taraxacum vulgare	14
		Not limed	97·4	0·2	2·4	Taraxacum vulgare	
15	As plot 7 following double Nitrate of Soda, 1858-75	Limed ...	70·6	18·2	11.2	Plantago lanceolata	15
		Not limed	76·2	8·8	15·0	Plantago lanceolata	
17	Single Nitrate of Soda	Limed ...	74·1	0·9	25·0	Plantago lanceolata	17
		Not limed	65·3	0·2	34·5	Plantago lanceolata	
18	Potash, Sulphate Soda, Magnesia, and double Sulphate of Amm. 1905 and since	limed 6788 lb.	82·6	—	17·4	Rumex acetosa	18
		,, 3951 lb.	86·0	—	14·0	Rumex acetosa	
		Not limed	91·2	—	8·8	Rumex acetosa	
19	Farmyard Dung in 1905 and every 4th year since (omitted in 1917)	limed 3150 lb.	92·3	4·0	3·7	Conopodium denudatum	19
		,, 570 lb.	92·3	2·3	5·4	Rumex acetosa	
		Not limed	88·8	5·1	6·1	Rumex acetosa; Centaurea nigra ...	
20	Farmyard Dung in 1905 and every 4th year since (omitted 1917), each intervening year Sulphate Potash, Super., and Nitrate of Soda ...	limed 2772 lb.	20·2	3·8	6·0	Rumex acetosa; Conopodium denudatum; Ranunculus spp.	20
		limed 570 lb.	91·0	4·8	4·2	Rumex acetosa	
		Not limed	90·2	4·0	5·8	Rumex acetosa	

The Park Grass Plots—*contd.*

BOTANICAL COMPOSITION, PER CENT. 1922, 1st CROP.

Plot.	Manuring.	Liming.	Gramineæ.	Leguminosæ.	Other Orders.	"Other Orders" consist largely of	Plot.
3	Unmanured	Limed ...	51·0	7·6	41·4	Centaurea nigra	3
		Not limed	60·5	4·6	34·9	Plantago lanceolata	
5-1	Unmanured, following double Ammonium Salts 1856-97	Not limed	57·2	2·1	40·7	Centaurea nigra	5-1
5-2	Super. and Sulph. Potash following double Ammonium Salts 1856-97 ...	Not limed	71·8	6·1	22·1	Rumex acetosa	5-2
7	Complete Mineral Manure	Limed ...	61·3	29·6	9·0	Heracleum sphondylium	7
		Not limed	69·7	12·7	17.5	Centaurea nigra	
9	Complete Mineral Manure & double Ammonium Salts	Limed ...	99·2	0·3	0·5	———	9
		Not limed	99·1	0·1	0·8	———	
14	Complete Mineral Manure & double Nitrate of Soda	Limed ...	92·5	1·1	6·4	Taraxacum vulgare	14
		Not limed	96·4	0·2	3·4	Taraxacum vulgare	
18	Potash, Sulphate Soda, Magnesia, and double Sulphate of Ammonia, 1905 and since.	limed 6788 lb.	82·3	1·4	16·3	Rumex acetosa	18
		,, 3951 lb.	87·5	—	12·5	Rumex acetosa	
		Not limed	80·7	—	19·3	Centaurea nigra	
19	Farmyard Dung in 1905 and every fourth year since (omitted in 1917)	limed 3150 lb.	86·2	7·2	6·6	Conopodium denudatum	19
		,, 570 lb.	88·1	5·9	5·9	Rumex acetosa; Ranunculus spp. ...	
		Not limed	85·8	7·5	6·7	Rumex acetosa	
20	Farmyard Dung in 1905 and every fourth year since (omitted in 1917), each intervening year Sulphate Potash, Super. and Nitrate of Soda	limed 2772 lb.	85·6	4·6	9·8	Conopodium denudatum	20
		,, 570 lb.	86.8	7·9	5·3	Conopodium denudatum	
		Not limed	90·9	1·0	8·1	Conopodium denudatum; Achillea millefolium	

WHEAT. BROADBALK FIELD, 1923.

Plot.	Manurial Treatment.	Top Portion. Dressed Grain. Yield per Acre. bush.	Top Portion. Dressed Grain. Weight per Bushel. lb.	Top Portion. Offal Grain per Acre. lb.	Top Portion. Straw per Acre. lb.	Top Portion. Total Straw per Acre. cwt.	Top Portion. Proportion of Total Grain to 100 of Total Straw.	Bottom Portion. Dressed Grain. Yield per Acre. bush.	Bottom Portion. Dressed Grain. Weight per Bushel. lb.	Bottom Portion. Offal Grain per Acre. lb.	Bottom Portion. Straw per Acre. lb.	Bottom Portion. Total Straw per Acre. cwt.	Bottom Portion. Proportion of Total Grain to 100 of Total Straw.	71 year Average 1852—1922. Dressed Grain per Acre. bush.	71 year Average 1852—1922. Total Straw per Acre. cwt.
2*A*	Farmyard Manure	12·5	63·4	124	1718	20·3	40·4	20·4	63·2	206	2470	29·2	45·7	28·4*	32·8*
2*B*	Farmyard Manure	13·5	63·3	155	2751	32·9	27·4	21·2	63·8	328	3060	37·5	40·0	34·3	34·6
3	Unmanured	3·8	62·8	27	332	3·7	65·4	4·2	62·9	37	298	3·7	71·6	12·1	9·9
5	Complete Mineral Manure	3·1	61·5	29	264	3·1	63·3	4·4	62·8	56	430	5·3	56·6	13·9	11·7
6	As 5, and Single Amm. Salts	6·2	62·0	61	813	9·9	40·0	7·9	63·1	69	828	9·7	52·2	22·3	20·7
7	As 5, and Double Amm. Salts	10·2	62·6	109	1824	20·9	31·8	15·8	63·5	300	2808	32·4	35·9	30·9	32·2
8	As 5, and Treble Amm. Salts	12·4	62·5	142	2708	30·2	27·1	17·8	63·3	388	3312	38·6	35·0	35·1	40·2
9	As 5, and Single Nitrate of Soda	8·3	62·0	81	1302	14·6	36·3	9·3	62·8	150	1924	23·0	28·5	24·5†	24·7†
10	Double Amm. Salts alone	7·6	62·0	84	1174	14·1	35·2	7·5	63·5	194	1396	19·8	30·1	19·1	18·0
11	As 10, and Superphosphate	6·5	62·2	100	1472	18·5	24·4	8·4	63·3	225	1902	24·1	28·0	21·5	21.7
12	As 10, and Super. and Sulph. Soda	7·8	62·4	108	1396	17·6	30·1	11·1	63·6	250	2096	25·3	33·8	27·6	27·2
13	As 10, and Super. and Sulph. Potash	12·2	63·3	113	1816	21·8	36·2	12·3	62·6	216	2748	30·3	29·0	29·8	31·0
14	As 10, and Super. and Sulph. Magnesia ...	10·5	63·3	135	1714	20·5	34·7	11·3	63·4	300	2270	27·6	32·9	27·3	27·2
15	Double Amm. Salts in Autumn and Minerals ...	17·4	63·3	126	1896	22·2	49·5	13·3	63·5	168	1972	23·4	38·6	28·4	28·7
16	Double Nitrate and Minerals	16·9	63·3	167	2224	26·5	41·7	11·8	61·0	275	2958	33·1	26·8	30·7†	35·8†
17	Minerals alone, or Double Amm. Salts alone in	2·9	61·5	39	356	4·7	40·9	5·0	62·4	76	698	9·2	37·6	28·6	28·6
18	alternate years	11·7	63·9	201	1620	20·0	42·3	11·8	63·4	192	2232	25·9	32·4	14·3	12·4
19	Rape Cake alone	13·6	63·4	232	1664	20·5	47·6	12·2	63·9	229	1918	24·4	36·8	22·0‡	22·7‡
20	Mineral Manure (without Super.) and Amm. Salts	8·6	63·0	122	1443	17·9	33·0	—	—	—	—	—	—	18·6§	19·8§

* 23 years only, 1900-1922. † 38 years only, 1885-1922. ‡ 30 years only, 1893-1922. § 15 years only, 1906-1922 (no crop in 1912 and 1914)

WHEAT. BROADBALK FIELD, 1924.

Plot.	Manurial Treatment.	Top Portion. Dressed Grain. Yield per Acre. bush.	Top Portion. Dressed Grain. Weight per Bushel. lb.	Top Portion. Offal Grain per Acre. lb.	Top Portion. Straw per Acre. lb.	Top Portion. Total Straw per Acre. cwt.	Top Portion. Proportion of Total Grain to 100 of Total Straw.	Bottom Portion. Dressed Grain. Yield per Acre. bush.	Bottom Portion. Dressed Grain. Weight per Bushel. lb.	Bottom Portion. Offal Grain per Acre. lb.	Bottom Portion. Straw per Acre. lb.	Bottom Portion. Total Straw per Acre. cwt.	Bottom Portion. Proportion of Total Grain to 100 of Total Straw.
2*A*	Farmyard Manure	10·3	60·3	142	1047	18·6	36·7	16·6	60·5	156	1417	22·2	46·5
2*B*	Farmyard Manure	10·4	59·5	158	1181	19·3	35·8	14·6	60·5	137	1367	22·4	40·6
3	Unmanured	2·1	58·9	25	188	3·6	36·4	2·2	58·9	23	136	2·8	47·3
5	Complete Mineral Manure	4·4	58·8	29	270	4·0	64·6	3·9	58·3	25	220	3·7	60·0
6	As 5, and Single Amm. Salts	10·2	60·0	52	827	11·2	52·7	9·1	60·5	43	554	7·6	69·9
7	As 5, and Double Amm. Salts	19·3	60·7	160	2182	28·9	41·2	24·1	60·9	136	1898	24·9	57·5
8	As 5, and Treble Amm. Salts	23·2	60·5	174	2826	35·8	39·4	23·7	60·0	148	2578	33·1	42·4
9	As 5, and Single Nitrate of Soda	12·9	59·6	107	1268	18·6	42·0	12·6	59·6	69	1012	13·5	54·1
10	Double Amm. Salts alone	4·9	59·0	72	532	11·4	28·2	5·4	58·9	85	434	8·3	43·1
11	As 10, and Superphosphate	5·5	58·3	111	944	16·6	23·1	4·6	58·0	109	632	12·8	26·3
12	As 10, and Super. and Sulph. Soda	9·1	59·4	128	910	15·7	38·0	9·3	58·5	129	1008	17·0	35·3
13	As 10, and Super. and Sulph. Potash ...	15·0	60·2	118	1420	21·2	42·9	11·0	60·0	85	1234	17·6	37·7
14	As 10, and Super. and Sulph. Magnesia ...	9·9	58·8	159	1260	18·0	36·6	8·6	58·8	129	948	14·8	38·3
15	Double Amm. Salts in Autumn and Minerals	7·9	59·0	91	836	14·0	35·7	4·6	58·1	66	532	10·9	27·3
16	Double Nitrate and Minerals	22·1	60·0	146	2168	32·8	40·0	19·3	59·5	156	1648	25·6	45·3
17	Minerals alone, or double Amm. Salts alone in	7·8	59·8	68	722	11·1	42·8	7·4	58·0	58	556	9·6	45·0
18	alternate years	7·8	59·5	39	480	6·7	67·4	8·4	59·0	46	560	7·8	61·7
19	Rape Cake alone	6·2	58·8	90	822	14·0	29·1	4·5	57·8	98	666	12·1	26·4
20	Mineral Manure (without Super.) and Amm. Salts	2·7	56·8	41	510	8·5	20·5	—	—	—	—	—	—

PERMANENT BARLEY PLOTS. Hoos Field, 1923, 1924.

PRODUCE PER ACRE.

Plot.	Manuring.	1923. Dressed Grain. Yield per Acre.	1923. Dressed Grain. Weight per Bushel.	1923. Offal Grain per Acre.	1923. Straw per Acre.	1923. Total Straw per Acre.	1923. Proportion of Total Grain to 100 of Total Straw.	1924. Dressed Grain. Yield per Acre.	1924. Dressed Grain. Weight per Bushel.	1924. Offal Grain per Acre.	1924. Straw per Acre.	1924. Total Straw per Acre.	1924. Proportion of Total Grain to 100 of Total Straw.	70 years Average Yield 1852—1922.† Dressed Grain per Acre.	70 years Average Yield 1852—1922.† Total Straw per Acre.
		bush.	lb.	lb.	lb.	cwt.		bush.	lb.	lb.	lb.	cwt.		bush.	cwt.
1 O	Unmanured	11·4	53·0	84	690	8·2	74·7	1·7	44·3	72	217	2·7	47·8	14·0	8·0
2 O	Superphosphate only	19·9	54·8	69	927	10·8	96·1	7·5	45·4	107	410	5·3	75·6	19·6	9·9
3 O	Alkali Salts only	13·6	52·1	54	916	11·1	61·5	1·7	44·0	72	195	3·0	44·3	15·0	8·8
4 O	Complete Minerals	17·2	53·6	66	996	11·4	77·0	2·5	44·8	101	289	4·7	40·5	19·8	11·1
5 O	Potash and Superphosphate ...	10·4	54·4	62	655	8·3	67·0	3·2	47·5	96	347	4·9	45·3	16·2	9·6
1 A	Ammonium Salts only	13·4	53·5	144	858	10·5	73·3	4·1	48·1	196	490	7·2	48·8	24·8	14·1
2 A	Superphosphate and Amm. Salts	23·3	54·3	108	1232	14·1	87·4	33·5	48·9	336	1680	18·6	95·0	37·0	20·9
3 A	Alkali Salts and Amm. Salts ...	16·5	54·3	149	1213	15·7	59·1	7·0	44·9	153	583	8·0	52·1	27·0	16·3
4 A	Complete Minerals and Amm. Salts	33·0	55·9	98	1598	18·2	95·3	28·4	49·0	343	1744	20·3	76·1	40·6	24·0
5 A	Potash, Super. and Amm. Salts ...	25·3	56·0	76	1336	15·6	85·7	28·4	49·0	216	1650	18·6	77·0	34·9	22·2
1 AA	Nitrate of Soda only	18·1	53·0	122	1320	15·1	64·0	5·7	48·3	227	699	10·5	42·8	25·3*	15·6*
2 AA	Super. and Nitrate of Soda ...	32·1	54·9	102	1656	18·4	90·4	32·0	47·8	342	1832	20·3	82·1	39·9*	23·5*
3 AA	Alkali Salts and Nitrate of Soda	17·0	54·3	123	1408	17·0	55·0	6·0	44·6	157	627	9·2	41·3	25·9*	16·8*
4 AA	Complete Minerals and Nitrate of Soda	31·2	56·1	107	1562	18·2	91·3	24·3	46·7	337	1700	21·3	61·7	39·2*	23·9*
1 AAS	As Plot 1 AA and Silicate of Soda	21·4	55·0	133	1397	16·5	71·1	10·0	48·3	221	908	11·8	52·9	31·6*	18·7*
2 AAS	,, ,, 2 AA ,, ,,	35·3	55·0	100	1711	18·8	96·9	26·3	48·3	278	1518	17·6	78·3	41·0*	24·5*
3 AAS	,, ,, 3 AA ,, ,,	23·3	54·3	107	1749	19·7	62·2	9·7	49·5	188	858	12·3	48·5	32·9*	20·4*
4 AAS	,, ,, 4 AA ,, ,,	36·0	55·9	96	1898	21·0	89·5	21·2	46·4	250	1469	17·9	61·4	41·5*	26·0*
1 C	Rape Cake only	28·1	54·9	78	1507	17·3	83·6	22·6	45·2	257	1287	15·1	75·7	36·5	20·9
2 C	Superphosphate and Rape Cake	36·0	55·8	89	1471	16·7	112·2	30·8	44·7	284	1612	18·3	80·9	38·8	22·3
3 C	Alkali Salts and Rape Cake ...	27·9	55·3	65	1474	17·2	83·6	17·9	45·0	219	1125	13·5	67·7	35·0	20·9
4 C	Complete Minerals and Rape Cake	35·2	54·9	65	1765	19·5	91·4	27·0	47·7	278	1689	19·5	71·8	38·5	22·9
7—1	Unmanured (after dung 20 years, 1852—71)	17·6	54·9	81	1106	12·7	73·5	2·2	46·5	107	297	4·7	39·7	24·0‡	14·1‡
7—2	Farmyard Manure	30·6	56·1	68	1856	19·3	82·3	28·4	49·9	212	2034	23·8	61·1	46·0	28·5
6—1	Unmanured	8·7	53·1	82	628	8·2	59·2	—	—	42	102	1·6	36·8	15·4	8·9
6—2	Ashes from Laboratory furnace ...	12·3	54·8	87	704	9·4	72·0	2·0	44·0	91	234	3·2	49·8	16·3	9·5
1 N	Nitrate of Soda only	18·3	54·0	144	1320	15·9	63·6	4·4	44·0	169	479	7·4	43·8	30·0§	18·3§
2 N	,, ,, ,, ...	23·1	55·0	119	1463	17·4	71·3	11·7	44·4	215	847	11·3	58·1	33·8§§	20·4§§

† 1912, all plots were fallowed. * 54 years, 1868—1922. ‡ 50 years, 1872—1922. § 69 years, 1853—1922. §§ 63 years, 1859—1922.

RED CLOVER grown year after year on rich Garden Soil, Rothamsted Garden.

Hay, Dry Matter, and Nitrogen per Acre, 1923 and 1924.

Year.	No. of Cuttings.	As Hay.	Dry Matter.	Nitrogen.	Seed Sown.
		lb.	lb.	lb.	
1923	2	1477	1231	37	1923 May mended
1924	2	794	663	20	1924 April mended
Averages:					
25 years, 1854—1878		7664	6387	179	
25 years, 1879—1903		3924	3270	101	
20 years, 1904—1923		2640	2200	65	

WHEAT AFTER FALLOW (without Manure 1851, and since).

Hoos Field, 1923 and 1924.

	1923.	1924.	Average 67 years 1856-1922.
Dressed Grain { Yield per Acre—bushels	2·8	1·6 lb.	15·22
Dressed Grain { Weight per Bushel—lb.	62·0	—	59·6
Offal Grain per Acre—lb.	42·0	1·5	52·0
Straw per Acre—lb.	459·0	18·0	—
Total Straw per Acre—cwt.	5·4	0·9	13·1
Proportion of Total Grain to 100 of Total Straw	35·9	3·1	—

AVERAGE WHEAT YIELDS *of* VARIOUS COUNTRIES.

Country.	Mean Yield per Acre 1901-10. bushels.	Country.	Mean Yield per Acre 1901-10. bushels.
Great Britain	31·6	Denmark	41·3
England	31·7	Argentine	10·6
Hertfordshire	30·5	Australia	10·1
France	20·2	Canada	19·5
Germany	29·1	United States	14·3
Belgium	35·1	Russia—European	10·0

NOTE.—Figures for Great Britain, England and Hertfordshire are taken from the Board of Agriculture's "Agricultural Statistics," Vol. 46. Other figures from "Annuarie International de Statistique Agricole," 1910-12, and converted at the rate of 60 lb. per bushel.

ROTATION PLOTS.

Little Hoos Field, 1923 and 1924.

Arranged to test the VALUE of VARIOUS MANURES in year of application and their RESIDUAL VALUE one, two, and three years after.

Produce per acre.

Plot.	Manure per Acre from 1919 onwards.	Season of Last Dressing.	1923 (20th Season), Clover. Yield per Acre. 1st Crop	2nd Crop	Total	Dry Matter per Acre. 1st Crop	2nd Crop	Total	1924 (21st Season), Wheat. Dressed Grain. Yield per Acre.	Weight per Bush.	Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.
			cwt.	cwt.	cwt.	lb.	lb.	lb.	bush.	lb.	lb.	lb.	cwt.	
A 1	Control	—	*24.0*	*26.1*	*50.1*	*2578*	*2163*	*4741*	*12.8*	*58.9*	*146*	*676*	*11.0*	*72.8*
2		1920	41.2	34.9	76.1	4002	2814	6816	46.2	60.0	190	3008	36.6	72.1
3	Ordinary Dung, 16 tons	1921	41.3	32.1	73.4	4312	2572	6884	39.0	60.8	197	2772	33.9	67.6
4		1922	43.2	30.7	73.9	4564	2495	7059	36.7	60.0	175	2416	28.9	73.3
5		1924	34.9	28.1	63.0	3605	2371	5976	**47.8**	**60.3**	**149**	**3248**	**37.5**	**72.2**
B 1	Cake fed dung, 16 tons	1920	40.6	34.1	74.7	4068	2702	6770	43.0	60.0	216	3016	36.1	68.9
2	Control	—	*26.4*	*27.6*	*54.0*	*2694*	*2148*	*4842*	*19.9*	*58.2*	*177*	*1180*	*16.1*	*73.7*
3		1921	44.4	34.4	78.8	4420	2716	7136	40.4	60.4	201	2728	32.5	72.4
4	Cake fed dung, 16 tons	1922	42.1	34.7	76.8	4345	2690	7035	40.7	59.9	189	2720	33.9	69.2
5		1924	38.4	30.1	68.5	3866	2453	6319	**43.6**	**60.8**	**215**	**3260**	**39.7**	**64.4**
C 1	Shoddy; Superphosphate; Sulphate of Potash ...	1920	26.1	26.4	52.5	2540	2144	4684	14.6	59.0	120	916	13.1	66.6
2		1921	17.7	28.1	45.8	1788	2258	4046	16.7	59.0	141	1052	15.0	66.7
3	Control	—	*16.6*	*28.0*	*44.6*	*1668*	*2235*	*3903*	*16.9*	*58.6*	*125*	*1004*	*13.8*	*72.3*
4	Shoddy; Superphosphate; Sulphate of Potash ...	1922	28.1	33.3	61.4	2837	2820	5657	20.1	58.5	132	1252	17.0	68.5
5		1924	20.3	27.1	47.4	1985	2178	4163	**33.4**	**59.7**	**135**	**2180**	**26.0**	**73.1**

D	1	Guano; Sulphate of Ammonia; Sulphate of Potash	1920	27·1	28·1	55·2	2762	2298	5060	20·3	59·8	160	1148	15·5	79·3
	2		1921	21·6	23·0	44·6	2179	1900	4079	16·8	59·3	156	1000	16·0	64·3
	3		1922	25·7	26·9	52·6	2644	2228	4872	18·3	58·3	124	1112	14·9	71·4
	4	Control	—	*24·3*	*27·9*	*52·2*	*2303*	*2278*	*4581*	*17·7*	*59·8*	*148*	*1112*	*16·7*	*64·6*
	5	Guano; Sulphate of Ammonia; Sulphate of Potash	1924	25·7	27·6	53·3	2600	2247	4847	**22·9**	**60·1**	**164**	**1416**	**20·8**	**66·2**
E	1	Rape Dust; Superphosphate; Sulphate of Potash	1920	25·5	27·1	52·6	2626	2070	4696	16·1	58·5	160	820	12·5	78·8
	2		1921	25·4	27·0	52·4	2598	2158	4756	21·1	59·4	174	1148	17·6	72·3
	3		1922	22·6	25·9	48·5	2298	2131	4429	18.2	59·0	161	1000	15·3	71·9
	4		1924	23·5	27·9	51·4	2397	2213	4610	**29·2**	**60·0**	**206**	**1912**	**27·6**	**63·3**
	5	Control	—	*31·4*	*31·6*	*63·0*	*3072*	*2520*	*5592*	*24·0*	*59·7*	*168*	*1408*	*20·4*	*70·3*
F	1	Control	—	*17·6*	*26·1*	*43·7*	*1825*	*2029*	*3854*	*7·8*	*58·0*	*129*	*444*	*10·2*	*50·7*
	2	Superphosphate; Sulphate of Ammonia; Sulphate of Potash	1920	20·1	24·1	44·2	1934	1875	3809	17·2	59·0	147	932	13·5	76·9
	3		1921	20·7	25·0	45·7	1945	1840	3785	20·3	59·8	162	1104	14·7	83·4
	4		1922	25·3	29·3	54·6	2454	2286	4740	19·9	60·0	133	1120	15·2	78·0
	5		1924	26·6	26·7	53·3	2667	2144	4811	**30·1**	**60·2**	**209**	**2176**	**28·1**	**64·4**
G	1	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	1920	20·4	24·4	44·8	1982	2060	4042	11·3	60·1	133	648	11·6	62·1
	2		1921	18·1	25·6	43·7	1791	2083	3874	21·7	60·3	130	1296	18·3	70·4
	3	Control	—	*20·1*	*23·0*	*43·1*	*1932*	*1896*	*3828*	*20·3*	*60·2*	*118*	*1244*	*15·8*	*75·6*
	4	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	1922	25·6	24·4	50·0	2503	1918	4421	21·7	60·5	104	1432	17·1	74·0
	5		1924	18·1	22·3	40·4	1777	1833	3610	**20·8**	**59·9**	**156**	**1560**	**22·0**	**56·9**
H	1	Basic Slag; Sulphate of Ammonia; Sulphate of Potash	1920	31·2	26·9	58·1	3113	2199	5312	29·1	60·8	156	1980	25·4	67·6
	2		1921	25·3	27·6	52·9	2426	2258	4684	32·6	60·6	181	2140	26·2	73·4
	3		1922	32·6	28·9	61·5	3178	2341	5519	32·8	60·2	184	2092	24·4	79·2
	4		1924	31·8	25·0	56·8	3146	2055	5201	**34·0**	**60·1**	**260**	**2952**	**33·4**	**61·6**
	5	Control	—	*27·9*	*22·0*	*49·9*	*2725*	*1778*	*4503*	*18·2*	*60·5*	*128*	*1416*	*17·3*	*63·2*

NOTES.—Since 1919 the manure for each plot (except of series A and B) has been rationed at 40 lb. Nitrogen, 100 lb. Calcium Phosphate and 50 lb. Potash per acre. Each plot has been supplied with as much of its particular manure (shoddy, guano, &c.) as possible without exceeding the receipt in any of the three rationed ingredients. Any deficit in either of these three has then been made good by adding the necessary quantity of Sulphate of Ammonia, Superphosphate, or Sulphate of Potash. No manure was applied for 1923 crop.

Figures in italics denote unmanured plots. The yields on the plots to which the manure was applied in a given season are printed in heavy type.

NITROGENOUS TRIALS.

Analyses of Manures used, 1923† and 1924.

Description.	% Nitrogen.
Sulphate of Ammonia	20·72
Muriate of Ammonia	24·75
Urea	46·65
Phosphazote (Tricalc. Phosphate 26·2%)	11·65

Except Top Dressing Oats, 1923.

MALTING BARLEY EXPERIMENTS.

Malting Barley (Plumage Archer). Long Hoos Field, 1923.

Manures per Acre.	Dressed Grain.		Offal Grain per Acre.	Straw per Acre.		Proportion of Total Grain to 100 of Total Straw.
	Yield per Acre. bushels	Weight per Bushel. lb.	lb.	Straw. lb.	Total Straw. cwt.	
Super. 3 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 1 cwt.	32·5	56·4	78	1762	19·9	85·7
Super. 3 cwt., Sul./Pot. 1½ cwt., Mur./Amm. 104 lb.	35·6	56·1	91	1787	19·9	93·6
Super. 3 cwt., Sul./Pot. 1½ cwt. ...	19·9	55·0	59	1212	15·2	67·6
Super. 3 cwt., Sul./Amm. 1 cwt. ...	34·2	55·5	69	1265	17·4	100·8
Super. 3 cwt., Sul./Amm. 1 cwt., Mur./ Pot. 1½ cwt.	37·2	56·1	95	1787	19·7	98·9
Sul./Amm. 1 cwt., Sul./Pot. 1½ cwt.	34·4	54·9	84	1675	18·4	96·1
No Manure	22·2	54·1	81	1288	14·5	79.2

Clover (after Malting Barley). Long Hoos Field, 1924.

Manures per Acre. Applied in 1923.	Yield per Acre.			Dry Matter per Acre.		
	1st Crop. cwt.	2nd Crop. cwt.	Total Crop. cwt.	1st Crop. lb.	2nd Crop. lb.	Total Crop. lb.
Super. 3 cwt., Sul./Pot. 1½ cwt., Sul./Amm. 1 cwt.	52·0	20·3	72·3	4796	1464	6260
Super. 3 cwt., Sul./Pot. 1½ cwt., Mur./Amm. 104 lb.	47·1	16·5	63·6	4149	1260	5409
Super. 3 cwt., Sul./Pot. 1½ cwt. ...	49·2	12·3	61·5	4439	936	5375
Super. 3 cwt., Sul./Amm. 1 cwt. ...,	46·4	11·6	58·0	4207	875	5082
Super. 3 cwt., Sul./Amm. 1 cwt., Mur./Pot. 1½ cwt.	50·2	15·4	65·6	4344	1120	5464
Sul./Amm. 1 cwt., Sul./Pot. 1½ cwt.	49·3	16·9	66·2	4493	1250	5743
No Manure	47·8	9·6	57·4	4226	734	4960

Manures applied April 17th, 1923.

Clover (after Malting Barley). Long Hoos Field, 1923.

Manuring per Acre, applied Spring 1922.	Yield per Acre. cwt.
Super. 3 cwt., Sulphate Potash 1½ cwt., Sulphate Ammonia 1 cwt.	36·8
Super. 3 cwt., Sulphate Potash 1½ cwt., Muriate Ammonia 93 lb.	37·1
Super. 3 cwt., Sulphate Potash 1½ cwt.	35·3
Super. 3 cwt., Sulphate Ammonia 1 cwt.	23·7
Super. 3 cwt., Sulphate Ammonia 1 cwt., Muriate Potash, 1½ cwt.	39·1
Sulphate Ammonia 1 cwt., Sulphate Potash 1½ cwt.	35·1
No Manure	31·0

Manures applied March 24th, 1922.

Malting Barley (Plumage Archer). Great Harpenden Field, 1924.

No. of Plot.	Manuring. Quantities per Acre.	Dressed Grain. Yield per Acre. bush.	Dressed Grain. Weight per bushel. lb.	Offal Grain per Acre. lb.	Straw per Acre. Straw. lb.	Straw per Acre. Total Straw. cwt.	Proportion of Total Grain to 100 of Total Straw.
1A	No Manure	27·2	53·8	172	1112	14·1	103·8
5B		22·6	52·6	200	863	12·1	102·8
6C		27·5	53·5	144	988	12·5	115·4
2A	Superphosphate 3 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1 cwt.	33·7	52·6	345	1575	18·5	102·0
6B		29·0	52·0	344	1338	16·4	100·7
4C		26·6	52·3	289	1188	14·6	102·5
3A	Superphosphate 3 cwt., Sulphate of Ammonia 1 cwt.	38·9	51·9	275	1663	19·1	107·1
7B		31·5	53·3	289	1388	17·0	103·4
2C		32·7	52·9	325	1575	19·5	94·0
4A	Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1 cwt.	32·4	52·4	247	1438	17·2	101·0
1B		30·8	52·8	369	1525	17·9	99·8
7C		28·7	53·4	291	1300	15·4	105·6
5A	Superphosphate 3 cwt., Sulphate of Potash 1½ cwt.	25·6	51·8	184	988	12·3	109·8
2B		22·7	51·8	211	938	12·3	100·6
5C		17·9	51·8	228	738	9·7	106·0
6A	Superphosphate 3 cwt., Muriate of Potash 136 lb., Sulphate of Ammonia 1 cwt.	30·6	53·3	328	1400	17·3	100·9
3B		27·4	51·4	369	1288	15·8	100·2
3C		28·0	52·3	366	1338	16·4	99·5
7A	Superphosphate 3 cwt., Sulphate of Potash 1½ cwt., Muriate of Ammonia 94 lb.	24·1	51·8	325	1138	14·2	99·0
4B		29·8	53·0	372	1450	18·1	96·3
1C		35·2	53·4	347	1663	20·2	98·5

Manures sown March 17th, 1924.

NITROGENOUS FERTILISER EXPERIMENTS, 1923 AND 1924.

Oats (Black Winter). Sawpit Field, 1923.

Treatment of Plots and Quantities per Acre.	Date of Application of Top Dressing.	Dressed Grain. Yield per Acre. bushels.			Dressed Grain. Weight per Bushel. lb.			Offal Grain per Acre. lb.			Straw per Acre. Straw. lb.			Straw per Acre. Total Straw. cwt.			Proportion of Total Grain to 100 of Total Straw.		
		Plot A	Plot B	Plot C	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C	Plot A	Plot B	Plot C
No Manure	—	27·3	29·4	22·4	44·3	42·8	43·0	300	288	241	1500	1600	1350	18·1	19·9	16·1	74·5	69·4	66·8
No Manure	—	27·7	33·1	24·9	42·0	43·5	43·5	284	350	231	1600	1875	1525	19·0	21·7	17·2	68·1	73·7	68·2
Superphosphate, 2 cwt.	—	28·5	34·0	25·0	43·3	42·5	42·8	256	234	244	1700	1875	1325	19·0	21·7	16·7	70·0	69·3	70·0
Sulphate of Ammonia, 1 cwt. ...	April 23rd	36·3	38·9	34·0	42·4	42·3	41·5	331	337	319	2200	2325	2075	25·0	25·9	23·9	66·7	68·3	64·7
Superphosphate, 1 cwt., Sulphate of Ammonia, 1 cwt.	April 23rd	37·1	38·2	32·9	42·0	42·0	42·0	300	347	266	2250	2275	2025	25·7	25·0	22·8	64·6	69·8	64·6
Superphosphate, 2 cwt., Sulphate of Ammonia, 1 cwt.	March 28th	39·8	33·5	38·7	44·3	42·9	43·3	400	294	366	2375	2000	2525	27·2	23·0	28·3	70·9	67·2	64·3
Superphosphate, 2 cwt., Sulphate of Ammonia, 1 cwt.	April 23rd	38·8	34·7	39·7	43·5	43·4	43·6	416	372	356	2375	2150	2450	27·2	25·4	28·3	69·0	65·9	65·7
Superphosphate, 2 cwt., Muriate of Ammonia, 103 lb....	April 23rd	41·4	44·9	49·0	44·1	43·3	43·5	419	353	372	2550	2775	2750	28·1	30·1	31·0	71·2	68·0	72·0
Superphosphate, 2 cwt., Sulphate of Ammonia, 1 cwt.	May 22nd	29·2	37·4	37·2	42·1	43·8	42·3	338	394	350	1700	2075	2025	20·1	24·8	23·4	69·7	73·2	73·2
Superphosphate, 4 cwt., Sulphate of Ammonia, 2 cwt.	March 28th	44·1	52·1	43·1	43·5	43·8	42·9	456	406	394	3050	3450	2725	35·5	37·3	31·3	59·7	64·4	64·1
Superphosphate, 2 cwt., Sulphate of Ammonia, 2 cwt.	March 28th	44·5	54·0	40·9	43·5	44·9	43·5	406	597	375	3125	3750	2725	35·0	41·3	30·6	59·7	65·3	62·9
Superphosphate, 2 cwt., Sulphate of Ammonia, 2 cwt.	April 23rd	40·7	48·0	47·4	44·3	43·8	43·5	372	506	397	2475	3350	2775	27·9	37·3	31·0	69·5	62·4	70·8
Superphosphate, 2 cwt., Muriate of Ammonia, 208 lb....	April 23rd	49·7	47·1	53·2	43·8	43·5	43·9	544	425	441	3250	2800	3325	36·6	32·4	37·1	66·3	68·3	66·9
Superphosphate, 2 cwt., Sulphate of Ammonia, 2 cwt.	May 22nd	54·5	49·4	57·3	42·0	40·8	41·9	606	500	513	3050	2575	3100	34·8	31·0	35·7	74·2	72·3	72·8

Barley (Plumage Archer). Long Hoos Field, 1923.

Manuring per Acre.	Dressed Grain. Yield per Acre. bushels.		Dressed Grain. Weight per Bushel. lb.		Offal Grain per Acre. lb.		Straw per Acre. Straw. lb.		Straw per Acre. Total Straw. cwt.		Proportion of Total Grain to 100 of Total Straw.	
	1st Plot.	2nd Plot.	1st Plot.	2nd Plot.	1st Plot.	2nd Plot.	1st Plot.	2nd Plot.	1st Plot.	2nd Plot.	1st Plot.	2nd Plot.
Super. 2 cwt., Sulphate of Ammonia 1 cwt. ...	22·7	22·9	56·0	55·5	100	94	1550	1500	18·6	17·1	65·7	71·2
Super. 2 cwt., Sulphate of Ammonia 2 cwt. ...	27·5	27·6	56·0	56·3	119	84	1925	1675	21·0	18·6	70·5	73·3
Super. 2 cwt., Muriate of Ammonia 93¾ lb. ...	25·4	24·9	56·3	55·5	88	84	1500	1450	17·5	16·2	77·2	80·8
Super. 2 cwt., Muriate of Ammonia 187½ lb. ...	23·5	34·3	55·5	55·9	116	97	1700	1950	19·6	21·1	64·6	85·2
Super. 2 cwt., Urea 49¾ lb.	26·8	22·5	56·1	56·0	103	72	1500	1325	16·6	15·5	86·2	76·6
Super. 2 cwt.	18·0	24·3	56·0	55·3	78	103	1200	1375	14·0	15·6	69·4	82·5
Control—No Manure	19·6	20·1	56·5	55·8	94	88	1275	1325	15·7	15·2	68·1	71·1

Barley (Plumage Archer). Great Harpenden Field, 1924.

Manuring per Acre.	Yield 1st Plot.	Yield 2nd Plot.	Weight 1st Plot.	Weight 2nd Plot.	Offal 1st Plot.	Offal 2nd Plot.	Straw 1st Plot.	Straw 2nd Plot.	Total Straw 1st Plot.	Total Straw 2nd Plot.	Proportion 1st Plot.	Proportion 2nd Plot.
Basal Manure (= Superphosphate 2 cwt., S/Pot., 1 cwt.)	22·2	25·5	52·0	52·8	197	169	1225	1200	14·1	14·1	85·9	96·2
Basal Manure, Sulphate of Ammonia 1 cwt. ...	29·7	37·8	50·8	51·9	272	234	1650	1875	18·8	20·5	84·7	95·5
Basal Manure, Sulphate of Ammonia 2 cwt. ...	45·4	40·1	52·5	52·3	247	322	2350	2200	25·7	23·7	91·4	91·2
Basal Manure, Muriate of Ammonia 94 lb. ...	36·3	33·4	52·8	52·3	212	281	1825	1675	20·8	19·0	91·4	95·3
Basal Manure, Muriate of Ammonia 188 lb. ...	47·2	43·3	53·0	52·5	256	338	2375	2050	26·1	22·8	94·2	102·5
Basal Manure, Urea 50 lb.	30·4	27·7	51·8	51·0	297	253	1750	1550	19·6	17·2	85·1	86·5
	41·2	31·8	52·0	52·0	222	241	2150	1700	22·8	18·8	92·8	90·2
Control—No Manure	22·5	24·3	52·0	53·0	212	175	1225	1200	13·8	14·1	89·3	92·9

1923, Nitrogenous Manures applied as top dressing on May 19th.
1924, Nitrogenous Manures applied with seed on March 15th.

Potatoes (Kerr's Pink).

Treatment of Plots and Manuring per Acre.	Produce per Acre. 1st Plot. Tons.	Produce per Acre. 2nd Plot. Tons.
Little Knott Field, 1923.		
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 3 cwt.*	15·6	14·9
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1½ cwt.	14·4	13·0
Superphosphate 4 cwt., Sylvinite 273½ lb., Sulphate of Ammonia 1½ cwt.	14·8	12·6
Superphosphate 4 cwt., Sylvinite 273½ lb.	12·8	10·8
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt.	12·0	12·0
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Muriate of Ammonia 2½ cwt.	14·0	13·9
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 3 cwt.	15·4	14·9
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 4½ cwt.*	14·9	14·7
Superphosphate 8 cwt., Sulphate of Potash 3 cwt., Sulphate of Ammonia 3 cwt.	16·6	14·9
Superphosphate 8 cwt., Sulphate of Potash 3 cwt., Sulphate of Ammonia 4½ cwt.*	16·3	16·0
Foster's Field, 1924.		
Control. No Manure	5·4	7·5
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt.	8·3	7·8
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 1½ cwt.	9·0	10·0
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 3 cwt.	10·2	8·6
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 3 cwt.*	8·4	9·9
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Sulphate of Ammonia 4½ cwt.*	10·0	9·9
Superphosphate 4 cwt., Sulphate of Potash 1½ cwt., Muriate of Ammonia 2½ cwt.	8·6	10·2
Superphosphate 8 cwt., Sulphate of Potash 3 cwt., Muriate of Ammonia 5 cwt.	11·7	10·3
Superphosphate 8 cwt., Sulphate of Potash 3 cwt., Muriate of Ammonia 7½ cwt.†	10·3	10·7

* 1½ cwt. given as Top Dressing. † 2½ cwt. given as Top Dressing.

Date of application of Manures :—1923, May 12th and 14th; Top Dressings July 14th. 1924, May 9th ; Top Dressings, July 9th.

Swedes (Hurst's Monarch). Foster's Field.

Treatment of Plots and Manuring per Acre.	Produce per Acre.			
	Roots.		Leaves.	
	1st Plot. Tons.	2nd Plot. Tons.	1st Plot. Tons.	2nd Plot. Tons.
1923.				
Superphosphate 5 cwt., Muriate of Potash 1 cwt., Dung 10 tons	14·2	14·4	1·5	1·3
Superphosphate 5 cwt., Muriate of Potash 1 cwt., Dung 10 tons, Sulphate of Ammonia 2 cwt.* ...	17·1	16·4	1·8	1·6
Superphosphate 5 cwt., Muriate of Potash 1 cwt., Sulphate of Ammonia 2 cwt.*	16·0	15·4	1·6	1·5
Superphosphate 5 cwt., Muriate of Potash 1 cwt. ...	13·5	12·9	1·3	1·2
1924.				
Control. No Manure	24·3 20·5	23·0 28·5	3·3 2·1	2·9 3·5
Superphosphate 5 cwt., Sulphate of Potash 1 cwt. ...	27·5 22.0	26·2 27·0	3·0 2·3	3·2 3·1
Superphosphate 5 cwt., Sulphate of Potash 1 cwt., Sulphate of Ammonia ¾ cwt.§	27.2	25·0	3·0	2·9
Superphosphate 5 cwt., Sulphate of Potash 1 cwt., Sulphate of Ammonia 1½ cwt.§	28·8	27·6	3·3	3·2
Superphosphate 5 cwt., Sulphate of Potash 1 cwt, Sulphate of Ammonia 1½ cwt.†	26·0	28·7	3·3	3·3
Superphosphate 5 cwt., Sulphate of Potash 1 cwt., Sulphate of Ammonia 2¼ cwt.‡	28·2	28·7	3·8	3·5
Superphosphate 5 cwt., Sulphate of Potash 1 cwt., Sulphate of Ammonia 2¼ cwt.†	26·4	28·2	3·6	3·6
Superphosphate 5 cwt., Sulphate of Potash 1 cwt., Sulphate of Ammonia 2¼ cwt.§	27·3	27·6	3·4	3·5

* Applied as top dressing. July 14th, 1923.
§ Applied as top dressing. July 9th, 1924.
† ¾ cwt. applied as top dressing. July 9th, 1924.
‡ 1½ cwt. applied as top dressing. July 9th, 1924

POTASSIC TRIALS.

Analyses of Manures, 1923 and 1924.

Description.	% K_2O 1923	% K_2O 1924
Sulphate of Potash	51·90	47·55
Muriate of Potash—High Grade	62·85	—
Muriate of Potash—Low Grade	56·35	51.36
Potash Manure Salts 30%	31·35	30·33
Potash Manure Salts 20%	21·35	22·21
Sylvinite	17·20	18·13
Kainit	13·45	—

Potatoes (Kerr's Pink). Foster's Field, 1924.

Manures per Acre. — Produce per Acre in Tons.

* Farmyard Manure Series (15 tons per Acre).

Manures per Acre.	Series D.	Series E.	Series F.	Series G.
Control. Farmyard Manure 15 tons	7·2	8·2	8.4	7·6
Basal Manure (Superphosphate 4 cwt., Sulphate of Ammonia 1½ cwt.)	9·7	9·9	9·2	7·9
Sulphate of Potash 191 lb., Basal Manure	8·8	8·6	8·8	9·1
Muriate of Potash 177 lb., Basal Manure	9·1	8·6	8·7	8·4
20% Potash Manure Salts, 408 lb., Basal Manure	9·4	9·5	8·6	9·4
Sylvinite 566 lb., Basal Manure	8·5	9·1	9·5	9·9

† No Farmyard Manure Series.

Manures per Acre.	Series W.	Series X.	Series Y.	Series Z.
Control. No Manure	5·0	4·7	5·5	5·2
Basal Manure (Superphosphate 6 cwt., Sulphate of Ammonia 2 cwt.)	7·9	6·1	6·0	4·8
Sulphate of Potash 255 lb., Basal Manure	7·6	8·2	6·7	6·6
Muriate of Potash 234 lb., Basal Manure	7·8	7·4	6·2	7·2
20% Potash Manure Salts 544 lb., Basal Manure	7·4	8·8	7·0	7·9
Sylvinite 6¾ cwt., Basal Manure	7·8	8·0	8·1	7·6
Sulphate of Potash 255 lb., Sulphate of Soda 830 lb., Basal Manure	8·2	7·0	7·5	7·9
Muriate of Potash 234 lb., Calcium Chloride 525 lb. Basal Manure	7·7	7·5	7·9	8·2

§ Potatoes (Kerr's Pink). Foster's Field, 1924.

Manures per Acre.	Series 1.	Series 2.	Series 3.
Control. No Manure	6·7	6·8	6·4
Sulphate of Potash 256 lb., Superphosphate 6 cwt., Sulphate of Ammonia 226 lb.	10·5	9·9	7·6
Superphosphate 6 cwt., Sulphate of Ammonia 226 lb.	10·0	8·1	3·4
Sulphate of Potash 512 lb., Superphosphate 12 cwt., Sulphate of Ammonia 452 lb.	11·9	9·3	10·5
Sulphate of Potash 125 lb., Superphosphate 3 cwt., Sulphate of Ammonia 113 lb.	9·1	8·1	6·2

* Manures applied, May 5-6th. † Manures applied, April 29th—May 5th.
§ Manures applied, May 15th.

Potatoes (Kerr's Pink). Sawyer's Field, 1923.

Manuring per Acre.	Yield per Acre. 1st Plot.	2nd Plot.	3rd Plot.
With Dung, 15 tons per Acre.	Tons.	Tons.	Tons.
Basal Manuring (Superphosphate 4 cwt., Sulphate of Ammonia 1½ cwt.)	11·2	12·6	11·3
Muriate Potash 144 lb., Sul./Mag. 171 lb., Salt 452 lb., Basal...	12·0	11·8	12·2
Muriate Potash 144 lb., Sul./Mag. 171 lb., Basal	12·6	12·3	14·2
Muriate Potash 144 lb., Salt 452 lb., Basal	10·6	11·7	12·4
Muriate Potash (High Grade) 144 lb., Basal	12·0	14·5	12·6
Muriate Potash (Low Grade) 161 lb., Basal	13·0	13·9	13·0
Potash Manure Salts 30% 290 lb., Basal	11·1	13·0	12·1
Potash Manure Salts 20% 424 lb., Basal	12·3	12·6	10·9
Sulphate Potash 178 lb., Basal	11·1	12·9	13·4
Sulphate Potash Mag. 328½ lb., Basal	12·1	12·1	14·5
Kainit 682 lb., Basal	12·4	10·3	12·2
Sylvinite 527 lb., Basal	9·8	9·7	11·9
No Artificial Manure	10·3	9·1	12·0
Without Dung.			
Basal Manuring (Superphosphate 6 cwt., Sulphate of Ammonia 2 cwt.	9·9	12·1	7·2
Muriate Potash 192½ lb., Sul/Mag. 228 lb., Salt 602½ lb. Basal	12·6	12·0	11·5
Muriate Potash 192½ lb., Sul/Mag. 228 lb., Basal	13·2	12·2	14·2
Muriate Potash 192½ lb., Salt 602½ lb., Basal	12·1	11·9	11·8
Muriate Potash (High Grade) 192½ lb., Basal	11·5	13·0	11·5
Muriate Potash (Low Grade) 215 lb., Basal	11·9	14·1	12·9
Potash Manure Salts 30% 386 lb., Basal	11·3	13·0	10·0
Potash Manure Salts 20% 565 lb., Basal	11·0	13·0	9·7
Sulphate Potash 237 lb., Basal	12·7	12·3	11·7
Sulphate Potash Mag. 438 lb., Basal	12·5	12·4	13·3
Kainit 908 lb., Basal	12·7	10·9	10·2
Sylvinite 702 lb., Basal	10·1	11·5	10·2
No Manure	6·9	8·4	8·6

NOTE: The potatoes when lifted were wet and dirty. Manures applied May 2nd, 3rd and 4th.

PHOSPHATIC TRIALS, 1923 AND 1924.

Analyses of Manures used.

No.	Description.	Total Phosphate as Tricalcic Phosphate.	Solubility %
Slag 1	Open Hearth Low Grade, High Sol.	25·0	90·4
,, 2	Open Hearth Low Grade, Low Sol.	18·0	35·7
,, 8	Open Hearth L. G. and Nauru Mineral Phosphate	53·1	25·5
,, 9	Open Hearth L. G., H. S. and Precipitated Bone Phosphate (4 : 1)	31·5	92·8
,, 10	Open Hearth L. G., H. S. and Gafsa Mineral Phosphate (3 : 7)	47·0	35·0
,, 12	Talbot Process H. G., H. S.	37·0	80·7
,, 13	Open Hearth L. G., H. S.	22·7	91·5
,, 14	Open Hearth L. G., L. S.	22·6	29·0
,, 20	Open Hearth L. G., H. S.	17·2	78·8
,, 21	Open Hearth L. G., L. S.	21·3	31·4
,, 22	Open Hearth L. G., H. S.	24·4	95·4
,, 23	Open Hearth H. G., L. S.	30·3	20·3
,, 24	Open Hearth H. G., H. S.	29·6	92·1
,, 25	Talbot Process H. G., H. S.	37·1	—
Mineral Phosphates.	Gafsa (1921—1923 Expts.)	62·9	—
Mineral Phosphates.	Gafsa (1924 Expts.)	55·0	—
Mineral Phosphates.	Nauru	83·0	—
Mineral Phosphates.	Tunisian	64·8	—
Mineral Phosphates.	Florida	74·8	—

SLAG APPLIED IN SEASON OF GROWTH.

Clover. Long Hoos Field, 1924.

Manuring Per Acre.*	Produce Per Acre.						Dry Matter per Acre.					
	1st Crop.			2nd Crop.			1st Crop.			2nd Crop.		
	A Series cwt.	B Series cwt.	C Series cwt.	A Series cwt.	B Series cwt.	C Series cwt.	A Series cwt.	B Series cwt.	C Series cwt.	A Series cwt.	B Series cwt.	C Series cwt.
Slag No. 21, 100 mesh, 1028 lb. ...	40·7	49·0	50·0	22·6	17·3	12·1	3956	4628	4513	1845	1484	1025
Slag No. 22, 100 mesh, 896 lb. ...	41·4	48·8	48·8	19·8	20·2	11·9	3963	4686	4570	1693	1696	1047
Superphosphate 596 lb.	42·6	49·2	60·4	21·8	13·5	11·1	3869	4667	5350	1828	1160	931
Gafsa Phosphate 398 lb.	43·8	48·0	48·9	23·8	15·9	11·9	3973	4556	4372	2037	1346	1014
Sulphate of Potash 1 cwt. (= Basal) ...	42·7	46·3	50·0	18·6	21·3	11·1	4065	4273	4447	1624	1764	950
Control : No Manure	40·9	46·2	40·0	17·6	21·0	13·4	3333	4415	3642	1515	1770	1157

* All plots (except Control) received a basal dressing of 1 cwt. Sulphate of Potash per acre. Phosphate Dressings are at the rate of 100 lb. P_2O_5 per acre.

Slags applied January 24th, 1924.

Swedes (Hurst's Monarch). Foster's Field 1924.

Produce per Acre.

Manurial Treatment. Quantities per Acre.	Roots.			Leaves.		
	A Series. Tons.	B Series. Tons.	C Series. Tons.	A Series. Tons.	B Series. Tons.	C Series. Tons.
Control: No Manure	17·0	18·6	16·2	2·9	3·5	3·0
Basal Manure (Sulphate of Ammonia 186 lb., Sulphate of Potash 93 lb.) ...	18·7	19·3	19·3	3·2	3·9	3·8
Slag No. 21, 100 mesh, 772 lb., Basal Manure	19·5	19·5	17·0	3·7	4·1	3·3
Slag No. 22, 100 Mesh, 672 lb., Basal Manure	19·5	19·5	18·2	3·4	3·6	3·7
Gafsa Phosphate 248 lb., Basal Manure	19·9	19·2	18·7	3·5	4·0	3·6
Superphosphate 3½ cwt., Basal Manure...	20·9	21·6	19·2	3·8	4·4	3·6

Slags applied June 18th, 1924.

Barley (Plumage Archer). Great Harpenden Field, 1924.

Manurial Treatment. Quantities per Acre.	Dressed Grain. Yield per Acre in bushels.			Dressed Grain. Weight per Bushel in lb.			Offal Grain per Acre. lb.			Straw per Acre. Straw. lb.			Straw per Acre. Total Straw. cwt.			Proportion of Total Grain to 100 of Total Straw.		
	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.
Control: No Manure ...	16·1	24·5	22·9	50·0	50·6	51·8	158	170	210	1000	1240	1160	12·5	15·0	13·4	68·8	83·9	93·0
Basal Manure (Sulphate of Potash, 1 cwt.; Sulphate of Ammonia, 107 lb.) ...	31·5	25·7	31·0	51·5	52·9	52·3	185	315	215	1500	1420	1640	16·8	17·9	18·4	96·0	83·8	89·0
Slag No. 21, 100 mesh, 514 lb.; Basal Manure ...	26·8	41·5	25·3	50·5	51·8	52·0	315	265	273	1560	1840	1640	17·3	20·5	17·3	86·1	104·8	81·8
Slag No. 22, 100 mesh, 447 lb.; Basal Manure ...	24·7	41·3	27·3	51·5	51·8	49·8	280	215	328	1420	1960	1500	17·1	22·0	18·4	80·7	95·5	81·9
Superphosphate, 298 lb.; Basal Manure	—	33·6	—	—	52·3	—	—	220	—	—	1720	—	—	19·3	—	—	91·4	—
Gafsa Phosphate, 157 lb.; Basal Manure	27·7	29·9	26·7	50·5	50·9	51·0	255	263	280	1500	1480	1500	16·1	17·0	17·1	91·9	93·8	85·4
Control. No Manure ...	14·7	24·3	13·8	49·3	50·5	51·0	220	212	223	840	1180	880	12·0	14·8	11·1	70·5	86·7	74·8
Basal Manure (Sulphate of Potash 1 cwt., Sulphate of Ammonia 107 lb.) ...	34·8	27·1	29·4	50·4	50·9	49·8	308	293	283	1640	1440	1660	19·8	16·6	18·4	92·9	89·9	84·6
Slag No. 23, 100 mesh, 360 lb., Basal Manure ...	23·2	24·3	20·0	49·5	50·3	49·0	325	348	345	1380	1500	1280	15·9	17·5	15·0	82·9	80·0	78·9
Slag No. 24, 100 mesh, 370 lb., Basal Manure ...	24·2	21·9	27·0	49·0	49·5	51·5	328	398	245	1400	1200	1420	15·9	14·1	16·6	85·0	93·8	87·9

Slags applied December 21st, 1923.

RESIDUAL EFFECT OF PHOSPHATES.

Hay. Great Field,* 1923.

No. of Plot.	Treatment of Plot and Quantities per Acre.	Yield per Acre. cwt. Series A.	Yield per Acre. cwt. Series B.	Dry Matter per Acre. lb. Series A.	Dry Matter per Acre. lb. Series B.
1	High Grade Slag No. 12, 1170 lb.	33·0	35·0	2755	2929
2	Open Hearth Slag No. 13, 1925 lb. (High Soluble)	28·3	36·0	2382	2948
3	Open Hearth Slag No. 14, 1930 lb. (Low Soluble)	30·9	39·6	2518	3219
4	Gafsa Phosphate, 750 lb.	33·6	37·4	2733	3036
C	No Manure	31·2	39·5	2686	3218
C 1	High Soluble Slag No. 1, 872 lb.	31·5		2570	
2	Low Soluble Slag No. 2, 1225 lb.	38·3		3011	
3	Gafsa Phosphate, 347 lb.	39·9		3051	
4	Tunisian Phosphate, 336 lb.	37·8		2782	
5	Florida Phosphate, 292 lb.	35·5		2911	
7	Nauru Phosphate, 263 lb.	35·2		2829	
D 7	Nauru Phosphate, 263 lb.	36·4		3058	
C 8	Slag Phosphate, Low Grade No. 8, 411 lb. ...	36·6		3042	
D 8	Slag Phosphate, Low Grade No. 8, 411 lb. ...	41·1		3215	
C	Control. No Manure	28·0		2284	
D	Control. No Manure	38.4		3059	

* Manures on the A and B series applied in January, 1921.
Manures on the C and D series applied in December, 1921.

Hay. Great Field, 1924.

Plot.	Manurial Treatment. Quantities per Acre.	Yield per Acre. No Potash. cwt.	Yield per Acre. With Potash. cwt.	Dry Matter per Acre. No Potash. lb.	Dry Matter per Acre. With Potash. lb.
1 A	High Grade Slag, No. 12, 1170 lb.	30·4	29·5	2807	2661
1 B		34·3	30·5	3082	2717
2 A	Open Hearth Slag, No. 13, 1925 lb.	25·7	28·2	2365	2555
2 B		33·9	26·6	2965	2406
3 A	Open Hearth Slag, No. 14, 1930 lb.	31·4	27·5	2794	2422
3 B		28·2	26·1	2454	2399
4 A	Gafsa Phosphate 750 lb.	39·6	29·1	3400	2598
4 B		29·3	29·3	2625	2578
A C	Control. No Manure	27·7	30·0	2587	2658
B C		36·8	30·4	3132	2651
7 C	Nauru Phosphate 263 lb.	30·5	31·6	2759	2884
7 D		30·5	30·5	2855	2670
8 C	Nauru Slag Phosphate, No. 8, 411 lb. ...	29·6	30·4	2727	2778
8 D		25·5	27·9	2341	2523
1 C	High Soluble Slag, No. 1, 872 lb.	28·4	30·5	2519	2647
2 C	Low Soluble Slag, No. 2, 1225 lb.	29·8	32·0	2723	2886
3 C	Gafsa Phosphate, 347 lb.	29·1	32·7	2672	2839
4 C	Tunisian Phosphate, 336 lb.	29·1	33·6	2408	2936
5 C	Florida Phosphate, 292 lb.	30·2	31·6	2767	2777
C C	Control. No Manure	27·5	32·0	2454	2827
D C		27·0	26·6	2455	2404

Kainit at 4 cwt. per acre, applied January 28th, 1924.

Clover. New Zealand Field, 1923.

No. of Plot.	Treatment of Plot and Quantities per Acre.	Yield per Acre. cwt.	Dry Matter per Acre. lb.
8	Slag Phosphate, No. 8, 376 lb.	34·1	3502
10	Slag Phosphate, No. 10, 424 lb.	34·0	3461
12	Low Grade, No. 20, 1176 lb.	32·6	3241
2	Open Hearth Slag, No. 2, 1100 lb.	29·3	2967
9	Slag, No. 9, 636 lb.	31·0	3099
C	Control. No Manure	32·0	3273

Clover. Stackyard Field, 1923.

No. of Plot.	Treatment of Plot and Quantities per Acre.	Yield per Acre. cwt.	Dry Matter per Acre. lb.
5	Florida Phosphate	24·8	2431
3	Gafsa Phosphate	22·9	2145
11	Phosphate, No. 25, 540 lb.	20·3	2073
4	Constantine Phosphate, 308 lb.	22·1	2253
7	Nauru Phosphate, No. 7, 241 lb.	21·5	1951
C	Control. No Manure	23·7	2411

Slags applied January 25th, 1923.

Clover (after Barley 1922.) Long Hoos Field, 1923.

Treatment of Plots in Spring 1922.	Yield per Acre. cwt.			Dry Matter per Acre. lb.		
	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.
Basal Manuring, Slag, full quantity ...	36·4	36·4	36·4	3648	3553	3532
	44·6	38·8	42·2	4376	3736	4098
Basal Manuring, Slag, half quantity; Gafsa Phosphate, 87 lb.	38·6	35·9	41·5	3747	3508	4100
	37·1	43·8	41·7	3169	4234	4064
Basal Manuring, Gafsa Phosphate, 174 lb.	37·1	33·5	40·0	3630	3235	3964
Basal Manuring only	34·6	40·9	45·5	3423	3959	4392
No Manure	42·2	35·1	36·8	4123	3471	3531

Basal Manuring is 1 cwt. Sulphate of Potash; 1 cwt. Sulphate of Ammonia. Full Quantity Slag represents 636 lb. Slag No. 20, 602 lb. Slag No. 2 and 436 lb. Slag No. 1 per acre.

Date of application of Slags { No. 20, March 24th.
Nos. 2 and 1, March 26th.

Oats (Grey Winters). West Barnfield, **1923**.

No. of Plot.	Treatment of Plots in Season 1921 and Qauntities per Acre.	Dressed Grain. Yield per Acre. Bushels.		Dressed Grain. Weight per Bushel. lb.		Offal Grain per Acre. lb.		Straw per Acre. Straw. lb.		Straw per Acre. Total Straw. cwt.		Proportion of Total Grain to 100 of Total Straw.	
		Series A.	Series B.	Series A.	Series B.	Series A.	Series B.	Series A.	Series B.	Series A.	Series B.	Series A.	Series B.
1	High Grade Slag No. 12, 1170 lb. ...	48·2	53·1	42·0	39·9	401	549	2740	3195	31·6	36·9	68·6	64·5
2	Open Hearth, High Soluble Slag No. 13, 1925 lb.	52·9	51·1	39·5	40·2	400	475	3200	3255	36·9	35·9	60·3	62·8
3	Open Hearth, Low Soluble Slag No. 14, 1930 lb.	52·7	54·1	41·9	40·4	543	525	3090	3210	33·9	34·8	72·4	69·5
4	Gafsa Phosphate, 750 lb.	52·5	50·9	41·3	39·7	548	568	3090	2770	33·8	29·5	71·9	78·4
C	No Manure	47·2	54·0	41·0	39·7	539	554	3075	2990	35·8	32·3	61·7	74·5
C	No Manure	55·8		40·8		448		3020		31·9		76·3	

Slag applied, January 14th, 1921.

Wheat (Red Standard) after Swedes. Great Harpenden Field, 1923.

Manuring per Acre. (applied in Spring, 1922).	Dressed Grain.						Offal Grain per Acre. lb.			Straw per Acre.						Proportion of Total Grain to 100 of Total Straw.		
	Yield per Acre. Bushels.			Weight per Bushel. lb.						Straw. lb.			Total Straw. cwt.					
	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.	Slag No. 20.	Slag No. 2.	Slag No. 1.
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag full quantity ...	19·4	25·5	21·1	64·0	63·6	63·6	272	228	222	2200	2738	2125	23·6	28·3	22·0	57·5	58·4	63·5
	20·9	24·6	22·9	60·3	63·8	63·0	177	300	211	2000	2288	2425	20·8	22·8	25·4	61·6	73·1	58·1
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., Slag half quantity, Gafsa Phosphate 175 lb.	18·2	22·7	21·7	63·0	63·0	63·5	217	228	214	2025	2538	2262	21·1	26·5	23·9	57·7	55·8	59·3
	23·5	22·5	23·4	62·8	62·6	62·8	208	187	219	2388	1888	2225	24·3	19·3	24·3	61·6	73·8	62·0
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., No. 7 Nauru Phosphate 262½ lb.	19·7	22·7	23·8	62·8	63·8	62·9	284	231	212	2125	1975	2575	23·0	20·6	27·4	58·9	72·8	55·6
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt., No. 3 Gafsa Phosphate 350 lb.	22·9	21·1	24·6	62·8	59·1	63·8	284	122	252	2750	1925	2225	29·0	20·4	25·2	53·0	59·8	64·4
Sulphate Ammonia 2 cwt., Sulphate Potash 1 cwt.	26·0	23·9	20·7	63·9	63·4	63·1	186	241	202	2500	2163	2338	27·0	22·2	25·1	61·1	70·6	53·7
No Manure	22·8	19·2	23·0	64·3	63·0	63·0	294	208	217	2550	1950	2012	26·5	20·5	20·8	59·4	61·5	71·5

NOTE.—"Full Quantity" Slag is : No. 20, 1275 lb. per Acre. No. 2, 1225 lb. per Acre. No. 1, 875 lb. per Acre.
Date of application of Slags, May 8th, 1922.

MISCELLANEOUS EXPERIMENTS.

ORGANIC MANURE. GREEN MANURING.

Oats (Black Winter). Produce per Acre. Great Knott Field, 1924.

GREEN MANURING	No. of Plot.	Basal Manuring. Quantities per Acre. Applied August 13th, 1923.	Dressed Grain. Yield per Acre. bushels.		Dressed Grain. Weight per Bushel. lb.		Offal Grain per Acre. lb.		Straw per Acre. Straw. lb.		Straw per Acre. Total Straw. cwt.		Proportion of Total Grain to 100 of Total Straw.	
			Plot 1.	Plot 2.	Plot 1.	Plot 2.	Plot 1.	Plot 2.	Plot 1.	Plot 2.	Plot 1.	Plot 2.	Plot 1.	Plot 2.
Mustard.*	M 1&4	10 Tons London Refuse ...	51·5	47·0	36·0	36·9	100	95	2840	2500	33·2	30·4	52·6	53·8
	M 2&5	5 Tons London Refuse ...	48·9	54·7	37·1	35·9	90	95	2300	2800	28·2	33·6	60·3	54·9
	M 3	Control. No Manure	43·3	—	36·8	—	120	—	2200	—	28·9	—	52·8	—
No Green Manuring.	C 1 & 4	10 Tons London Refuse ...	31·8	33·8	36·0	37·3	88	80	2080	1840	27·7	25·5	39·8	46·9
	C 2 & 5	5 Tons London Refuse ...	25·8	32·8	36·0	37·1	83	88	1560	1900	21·8	25·7	41·5	45·3
	C 3	Control. No Manure	27·5	—	37·5	—	80	—	1520	—	20·4	—	48·7	—
No Green† Manuring.	H 1 & 4	10 Tons London Refuse ...	30·1	26·8	36·8	36·9	75	73	1860	1500	23·4	20·7	45·0	45·7
	H 2 & 5	5 Tons London Refuse ...	25·3	24·4	36·5	36·8	70	83	1420	1480	18·6	20·7	47·8	42·2
	H 3	Control. No Manure	22·5	—	36·8	—	65	—	1200	—	17·5	—	45·4	—

* The Mustard crop was sown August 20th, 1923, and ploughed on October 18th, 1923.

† Hubam Clover was sown on this series for Green Manure, but the plant failed.

TOWN REFUSE EXPERIMENT.

Mangolds (Prizewinner Yellow Globe). Fosters Field, 1923.

Treatment of Plots and Manuring per Acre.	Yield per Acre.	
	Roots.	Leaves.
	Tons.	Tons.
Control. No Manure	9·6	3·2
Dung, 15 tons...	13·2	3·9
Hampstead Refuse, 15 tons...	14·0	3·4
Walworth Refuse, 15 tons	13·9	3·5

Manures applied May 4th.

PHOSPHAZOTE EXPERIMENT.

Potatoes (Kerr's Pink). Little Knott Field, 1923.

Manuring per Acre.	Yield per Acre.		
	1st Plot.	2nd Plot.	3rd Plot.
	Tons.	Tons.	Tons.
Control. No Manure	10·8	9·4	8·2
Sulphate of Potash 1¼ cwt.	12·4	9·8	10·1
Sulphate of Potash 1¼ cwt., Superphosphate 3 cwt., Sulphate of Ammonia 266⅔ lb.	14·2	13·8	13·9
Sulphate of Potash 1¼ cwt., Phosphazote 4¼ cwt.	12·8	13·2	12·7

Manures applied, May 12th-14th.

EFFECT OF STRAW AND MINERALS ON LEGUMINOSAE.

Produce per Acre. Little Hoos Field, 1923 and 1924.

Manures per Acre. Applied in 1923.	1923.			1924.		
	Beans and Straw.			Wheat and Straw.		
	1st Series.	2nd Series.	3rd Series.	1st Series.	2nd Series.	3rd Series.
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
5 tons Chaff	29·9	25·9	33·5	27·2	21·4	29·5
400 lb. Superphosphate	24·1	25·9	24·6	17·9	25·0	23·7
5 tons Chaff, 400 lb. Superphosphate ...	34·8	28·1	29·9	29·9	24·4	30·8
400 lb. Superphosphate, 200 lb. Sulphate of Potash	32·1	37·0	29·0	20·5	32·1	25·9
Control	25·0	26·3	26·8	18·8	21·9	21·0
	24·6	—	—	27·2	—	—

Lawes Agricultural Trust

Lord Bledisloe resigned in 1924 and was succeeded by Lord Clinton.

The Incorporated Society for Extending the Rothamsted Experiments

The purpose of this Society is to collect much needed funds for continuing and extending the work of the Rothamsted Station.

Bankers: Messrs. Coutts & Co., 15, Lombard Street, E.C.3.

Auditors: Messrs. W. B. Keen & Co., 23, Queen Victoria Street. E.C.4.

Memoranda

Memoranda